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AN EVALUATION OF TWO VERSIONS OF THE SJOSTRAND PHYSICAL WORK CAPACITY TEST

BY

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "An Evaluation of Two Versions of the Sjostrand Physical Work Capacity Test" submitted by Dennis E. Fedoruk in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

Accepting the Mitchell, Sproule, and Chapman Treadmill test as the criterion measure of maximal oxygen uptake, the study was designed to investigate the interrelationships of MVo_2 values determined from the modified Astrand Bicycle Ergometer technique, and physical work capacity 170 values determined from submaximal efforts on the modified Sjostrand work capacity test and a simulated Progressive Step test.

The experimental group consisted of twenty-four male and twenty-four female subjects randomly selected from the enrollment of first-year undergraduate students in the Faculty of Physical Education, University of Alberta. Each subject completed two Mitchell, Sproule, and Chapman Treadmill MVo_2 tests, an Astrand Bicycle Ergometer MVo_2 test, two modified Sjostrand PWC_{170} tests, two Progressive Step tests, and an estimate of body density.

Results indicated significant differences at the 0.05 level of significance between the criterion test and Astrand MVo_2 correlations and the correlations of the criterion test and the Progressive Step test for males and females. Significant differences at the 0.05 level of significance were found between the interrelationships of the criterion MVo_2 measures and the Sjostrand work capacity measures for the females. No significant differences at the 0.05 level of significance were found between the interrelationships of the criterion MVo_2 measures and the mean values of the Sjostrand work capacity tests for male subjects.

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CHAPTER I

STATEMENT OF THE PROBLEM

Introduction

Exercise physiologists generally agree that maximal oxygen uptake is probably the best measure of a person's physical fitness, where the definition of 'physical fitness' is restricted to the capacity of the individual for prolonged heavy work (4, 22). The measure of maximal capacity by the cardiovascular-respiratory system to take up, transport, and give off oxygen to the working tissue for use is a general, though accepted meaning of maximal oxygen consumption or aerobic capacity (22, 23, 28, 34, 46). It is often stated that the best measurement of the maximal function of the cardiovascular-respiratory system is indicated by maximal oxygen consumption.

In the same respect, consideration must be given to such frequently used terms as work capacity, physical condition, and physical fitness. Work capacity and maximal oxygen uptake are often used synonymously in the literature. Although similar to some extent, they are not synonyms.

Astrand and Ryhming (4) have devised a nomogram for the prediction of aerobic work capacity from submaximal work. Although they and others emphasize this method as a 'rough' prediction, it does reveal the existing difference between work capacity and maximal oxygen consumption.

Astrand and Rhyming (4), Wahlund (46), Cumming and Danzinger (15) have all attempted to link pulse rates and maximal oxygen consumption. Cumming and Danzinger (15) reported a mean oxygen consumption at a pulse rate of 170 beats per minute which was 73 percent of maximal oxygen consumption. Wahlund's (46) value for the same measure was 80 percent. Astrand (5) has described the quantitative and qualitative differences

between work capacity and physical condition respectively. Thus, it becomes apparent that the meaning of physical fitness, physical condition, work capacity, and maximal oxygen consumption are different.

Measurement of maximal oxygen consumption and work capacity generally employ the use of two general types of tests: (1) maximal tests, and (2) submaximal tests. The equipment generally used in testing includes the treadmill and/or the bicycle ergometer. Astrand (5) has devised a maximal oxygen uptake test which uses the bicycle ergometer. Mitchell et al (28) using the treadmill have developed a popular test for determining maximal oxygen consumption. A widely accepted work capacity test on the bicycle ergometer has been described by Sjostrand (40). As well, certain work capacity tests using various stepping methods have appeared in recent literature. These include only a few of many tests purporting to measure work capacity and maximal oxygen consumption (MVo_2).

The response induced in the subject generally classifies the exercise test as submaximal or maximal. The essential difference between the two tests is whether the subject is able to complete the task or is forced to stop exercising due to exhaustion. The intensity of a submaximal exercise cannot exceed the capacities of the poorest subject. However, a maximal test must bring all subjects within a comparable degree of exhaustion. Therefore, a test may be made a submaximal or maximal test by proper selection of the intensity necessary in relation to the physical capcity of the subject.

Two maximal oxygen uptake procedures and two submaximal work capacity tests have been chosen for this study. The two maximal tests chosen were the Mitchell, Sproule, and Chapman Treadmill Test (28), and the Astrand

Bicycle Ergometer Test as modified by Wahlund (46). The work capacity tests include the Sjostrand Physical Work Capacity 170 Test (40), and a Progressive Step Test.

As yet, no single submaximal work capacity test has been generally acknowledged as acceptable a measure of physical fitness to the same degree as a maximal oxygen uptake test. This study shall investigate the associations among the selected maximal and submaximal tests in the light that the more easily and often more convenient submaximal tests may prove as beneficial and accurate in assessing physical fitness as the maximal tests. Maximal oxygen consumption as determined from the Mitchell, Sproule, and Chapman technique was accepted as the criterion measure of fitness for the purposes of this study. Certain correlation values between maximal and submaximal tests have been cited by Hettinger et al (22), Glassford et al (21), Wahlund (46), and Cumming et al (15). Indeed, "quantitative assessment of physical fitness is one of the most complex and controversial problems in applied physiology" (25:535).

Problem

It was the purpose of this study to investigate the interrelationships between maximal oxygen uptake values, determined from the Mitchell, Sproule, and Chapman and Modified Astrand techniques, and the work capacity values as determined from submaximal efforts on the Sjostrand and Progressive Step tests.

Subsidiary Problems

In addition, the study also investigated:

1. The reliability between repeated trials on the Mitchell, Sproule, and Chapman test, the Sjostrand Bicycle Ergometer test, and the Progressive

Step test.

2. The interrelationships of the maximal and submaximal tests when the mean of the two submaximal trials was correlated with the criterion test.

Hypotheses

The following null hypotheses were tested for significance at the 0.05 level of significance.

1. There were no significant differences between the correlation of the criterion maximal test and another maximal test, and the correlation of the criterion maximal test and a submaximal work capacity test.

2. On the basis that the above hypothesis was not accepted, the subsidiary hypothesis stated that there were no significant differences between the correlation of the two maximal tests and the correlation of the criterion maximal test and the mean of two submaximal work capacity trials.

Justification for the Study

Physicians and physical educators are often concerned with the physical fitness of large populations. Although maximal oxygen consumption is most accurately assessed in the laboratory, it is often too expensive and inconvenient to accommodate a large field study. High interrelationships between maximal and submaximal tests would indicate that the latter tests could accurately predict maximal oxygen uptake.

Limitations

The temperature and humidity within the laboratory were not precisely controlled. The temperature varied within a $\pm$ 4 degree range of 72 degrees Fahrenheit.

Delimitations

The sample of subjects, consisting of 24 males and 24 females was chosen randomly from a class of first-year University of Alberta Physical Education and Recreation undergraduates.

Definition of Terms

1. Maximal oxygen consumption (MVo_2) is defined in terms of the linear relationship between progressively increasing work loads and oxygen consumption, until maximal oxygen intake per unit time remains constant, falls, or only slightly increases, even though work load may increase. The criterion values for the maximal tests are: (1) $\pm$ 54 milliliters of oxygen for the Mitchell, Sproule, and Chapman test (28), and (2) $\pm$ 80 milliliters of oxygen for the modified Astrand test (4).

2. Physical work capacity 170 (PWC_{170}) is defined as the intensity in kilopond meters per minute or kilogram meters per minute which the subject could perform at a pulse rate of 170 beats per minute (7). The Sjostrand physical work capacity principle is based on the linear relationship that exists between steady state pulse frequencies and the work loads producing these pulse frequencies. Plotting this approximate linear relationship, the value of PWC_{170} is determined by intrapolation or extrapolation.

3. Steady state heart rate is the heart rate between two successive readings, taken at one minute intervals, which does not differ by more than $\pm$ five beats.

4. A maximal test surpasses the aerobic energy stores of the metabolic system of the body and causes performance to continue only by anaerobic metabolism, which is an indication of maximal oxygen consumption.

5. A submaximal test does not surpass the aerobic limits of the body

nor purposely elicit a heart rate exceeding 180 beats per minute.

6. Work load is the calibrated force of a friction belt which must be overcome by a subject while cycling at a prescribed rate, or is the work done in lifting body weight a certain height at a prescribed stepping rate. The work done is a product of the cycling rate, the distance cycled as determined by the wheel circumference, and the belt resistance, or is the product of the vertical stepping height, body weight, and the frequency of stepping per minute. An adjustment in the percent grade or inclination of the running board determines the work load on the treadmill.

7. Kilopond meter (kpm) is the force developed by a kilogram mass under the influence of normal acceleration for one meter.

8. Kilogram meter (kgm) is the force required to raise a kilogram mass through a height of one meter.

CHAPTER II

REVIEW OF THE LITERATURE

Tests Under Study

Although many tests of maximal oxygen consumption and work capacity have been devised and are available, this study has been limited to the investigation of two maximal tests and two submaximal tests. The maximal oxygen consumption measures will be determined by the Mitchell, Sproule, and Chapman Treadmill test and the modified Astrand Bicycle Ergometer test. The submaximal work capacity values will be determined by the Sjostrand Physical Work Capacity 170 test and a Progressive Step test. Several methods for assessing the maximal oxygen consumption of individuals have been cited in the literature (5, 9, 28, 43). Numerous methods of assessing work capacity are also available (6, 31, 29, 44, 46). In general, these tests use the treadmill (5, 28, 43) or the bicycle ergometer (6, 16, 40). Recent literature has reported the development of several gradational or progressive step tests (30, 31, 36, 41). Several researchers feel that a well-designed stepping procedure may be as useful in determining cardio-vascular-respiratory efficiency as is the maximal oxygen consumption method.

Many physiologists consider maximal oxygen uptake as the best single measure of an individual's capacity to perform prolonged physical work. This capacity appears limited by the ability of the cardiopulmonary system to take up, transport, and give off oxygen to body tissue. However, the time and elaborate equipment necessary to make this evaluation tend to be disadvantages when testing very large samples as is necessary for normative studies.

In view of the above, several submaximal procedures for indirectly assessing cardiovascular-respiratory function were devised. The lower cost of equipment and ease in administration are assets in submaximal testing.

Another important aspect tends to be the submaximal effort required of the subject which makes testing of small children and elderly people possible. Therefore, an interest has been developed in assessing the results of work capacity measures with direct measures of maximal oxygen consumption with the view that submaximal testing will give a valid indication of an individual's cardiovascular-respiratory capacity to perform prolonged physical activity.

Studies Relating Submaximal Testing and MVo_2

Several studies have been designed to compare certain submaximal tests predicting maximal oxygen consumption with maximal uptake tests. As well, certain studies have attempted to link maximal oxygen consumption with heart rate or the respiratory quotient which is based on submaximal work. However, few studies have attempted direct correlations between maximal oxygen consumption and physical work capacity values.

Glassford et al (21) have compared maximal oxygen uptake values determined by predicted or indirect methods and by direct methods. Correlations were calculated among three direct tests, the (a) Mitchell, Sproule, and Chapman test, (b) Taylor, Buskirk, and Henschel Treadmill test, (c) Modified Astrand Bicycle Ergometer test, and an indirect test, the (d) Astrand-Ryhming Nomogram Bicycle Ergometer test. All four tests differed significantly from zero at the 0.01 level of significance. When expressed from values in liters per minute and milliliters per kilogram per minute, there were no significant differences among any of the correlations. The mean oxygen uptake values in liters per minute agreed with findings of Buskirk and Taylor (12), Mitchell et al (28), and Astrand (5). The results of the intercorrelations of all four tests gave further insight into the value of the Astrand-Ryhming nomogram (4) as an accurate predictor

of maximal oxygen uptake. Glassford et al (21) found significantly higher mean values of maximal oxygen uptake when using the Astrand-Ryhming nomogram prediction as compared to finding the values directly from the modified Astrand maximal test. Hettinger (22) reported the same results. Performance on the bicycle ergometer is limited mainly by localized exhaustion of the quadriceps muscles rather than be general circulatory exhaustion as caused by treadmill running. Astrand-Ryhming's nomogram is also based on the performance of well-trained athletes. The greater variance in the values of the nomogram prediction as reported by Glassford et al (21) suggests that further investigation into these differences is necessary before the nomogram can be used extensively in predicting maximal oxygen consumption.

Astrand and Saltin (7) have reported very little difference in determining maximal oxygen uptake from a variety of activities, however, their selection of subjects was very limited. The same may be said of similar studies by Binkhorst et al (9), Newton (33), and Wyndham et al (48).

Hettinger et al (22) proposed to make direct comparisons between maximal oxygen consumption and several selected fitness tests given to a sample of ninety-six male subjects. They reported significant correlations between maximal oxygen consumption and the following tests: (a) Harvard Step test, probability less than 0.001, (b) Master Step test, probability less than 0.05, and (c) Amplituden-puls-Frequenz test, probability less than 0.02. Using the Astrand-Ryhming nomogram, they reported a significant correlation at the 0.01 level of significance between actual and predicted maximal oxygen uptake values. However, the exact correlations were not stated. As well, a significant correlation was reported between the Harvard Step test and a Modified Step test which was adjusted for the

body weight and leg length of the subject. As a result, Hettinger supported use of the Harvard Step test as a simple method of assessing physical work capacity. Higher predicted maximal oxygen uptake values as opposed to actual maximal measures were explained as a result of Astrand-Ryhming's nomogram having been based on scores of exceptionally well-trained subjects.

Shephard et al (39), selecting oxygen uptake as the reference standard of cardio-vascular-respiratory fitness, reported values determined by three modes of exercise. Repeated testing of 24 subjects revealed that uphill treadmill running gave a maximum oxygen uptake value which was 3.4 percent higher than that found during stepping, and 6.6 percent higher than that found during cycling. These results conformed with those of Wyndham et al (48), Glassford et al (21), and Astrand and Saltin (7). Shephard also supported the widespread view that the directly measured maximal oxygen uptake value should be accepted as the absolute criterion against which other procedures are to be judged.

Taylor et al (44) gave an excellent review of factors influencing and affecting the administration and results of maximal and submaximal tests. Their review was well supported by a host of related studies (5, 17, 28, 40, 43, 44). A recent study by Glassford (20) has also reported that maximal oxygen uptake of a subject, when performing maximally, is relative to a special given set of circumstances. As supported by others, factors which influence oxygen uptake include, age, sex, body size, environmental temperature, training, functional capacities of the circulatory and respiratory systems, ingestion of food, fatigue, and emotion.

Step Tests Relating to Work Capacity and MVo_2

As reported by Chrastek et al (13), Keen and Sloan (27) showed that the fitness index results of a step test are not related to the height,

length of lower extremities, or to various other anthropometric indices. These findings are supported by studies of Cullumbine (14), and Fletcher (19).

A study by de Vries and Klafs (16) used six submaximal tests and evaluated these measures against an actual maximal oxygen uptake value for each subject. The results showed no significant correlation between scores of a modified Sjostrand stepping procedure and scores of MVo_2 when absolute values were used. However, when the MVo_2 values were normalized for weight, the correlation with the Sjostrand scores appeared significant with a correlation of .877. As well, the Harvard Step test and Progressive Pulse Ratio test showed correlations of .766 and .711 respectively. The modified Sjostrand stepping procedure used the step rate change method of determining different work loads. These tests had 16 male physical education majors as their sample.

Although not correlating MVo_2 and work capacity results, Shephard (38) has devised a stepping method which involves 'steady state' pulse rates at four graded intensities of effort. However, as with de Vries et al (16), the height remains constant as the rate of stepping changes from 10, 15, 20, to finally 25 ascents per minute. The work done in stepping is recorded in kilogram meters per minute per kilogram body weight of the subject.

Andersen (1) in an outline of "Measurements of Work Capacity" points out that in determining MVo_2 the order of preference in testing procedures should be initially the treadmill, and secondly, the bicycle ergometer. Although convenient for submaximal types of exercise, the step test is not suitable for the determination of MVo_2. Andersen also reported that the direct determination of MVo_2 is of the order three to five percent

greater than using the indirect method. This is supported by Rovelli and Aghemo (36) as well.

Kasch (26), in opposition to Andersen, found a .95 correlation between a treadmill method and step method of determining MVo_2 for twelve subjects. This particular step test was based on stepping rate change while the stepping height was kept constant.

Wyndham et al (49) reported relationships between oxygen uptake and work rates among ethnic groups which were tested on a one-foot bench. Fitted into a regression analysis, no significant differences were found between any of the three groups when the two variables were compared. Again the stepping rate changed while the height was kept constant.

Wyndham et al (47) obtained MVo_2 values from an intermittent treadmill test, a bicycle ergometer test, and a 'rate change' step test. Maximal oxygen uptake values determined on the maximal bicycle ergometer test were significantly lower than values obtained on the intermittent treadmill method. Wyndham concluded that using the bicycle ergometer technique in a population unaccustomed to cycling was an inaccurate method of assessing MVo_2. However, the step test and intermittent treadmill MVo_2 values showed a .95 probability that step test results would fall within a range of $\pm$ 0.95 liters of oxygen per minute of the treadmill values.

Nagle et al (30) have devised a gradational step test to assess work capacity of subjects. It was postulated that the final treadmill performance might be predicted from an extrapolation of the heart rates measured at the various stepping levels of the apparatus. From the gradational step test, which allowed a rate and height increase in performance, it was possible to measure energy expenditure as well as maximal oxygen consumption. Of the several methods investigated with the stepping techniques, one

of the procedures revealed a correlation of .95 between treadmill and stepping performances.

CHAPTER III

METHODS AND PROCEDURES

Subjects

The sample of 48 subjects was randomly chosen from a class of first-year University of Alberta Physical Education and Recreation undergraduates. The sample consisted of 24 males and 24 females.

The tests completed by each subject were: (1) two trials of the Mitchell, Sproule, and Chapman Treadmill test, (2) the modified Astrand Bicycle Ergometer test, (3) two trials of the Sjostrand Physical Work Capacity 170 test, and (4) two trials of the Progressive Step test. For each subject the criterion Mitchell, Sproule, and Chapman test was administered first and the remaining tests followed according to one of 24 possible permutations with each subject selecting a permutation at random. Testing for each subject was competed within three weeks with a minimum of two days between successive tests. Body density was estimated at the termination of the work capacity testing period.

Standardization of Subject Procedures

Certain conditions were to be met by the subjects prior to testing. Initially each subject was orientated to the apparatus and procedure of each test. Subjects were to refrain from eating, smoking, and any strenuous exercise one-and-one half hours prior to each test. In addition, a similar time was arranged for each testing session.

Administrators

Testers were thoroughly experienced with all phases of testing techniques, administration, and analysis.

Heart-Rate Recordings

The Sanborn VISO 100 Electrocardiogram was used to record heart rates. The disc electrodes were filled with Redux to ensure better conductivity.

Laboratory Conditions

The research laboratory at the University of Alberta, Faculty of Physical Education complex, was maintained at a temperature of 72 $\pm$ 4 degrees Fahrenheit.

Gas Collection and Analysis

Expired air was directed from the subject through a four flap triple-J valve and collected in 150-liter or 200-liter Douglas bags for analysis. The mouthpiece of the valve and connecting tubes were supported by a lightweight adjustable head-gear apparatus.

The Beckman model E-2 oxygen analyzer and Godhart Capnograph infra-red carbon dioxide analyzer were used to measure the percentages of the respective gases in each sample. The volume of expired air was measured by an American Meter Company Gasometer.

Calibration of the Instruments

The oxygen and carbon dioxide analyzers were carefully and regularly calibrated each day prior to and during testing. The calibration was done with gas samples of known nitrogen and carbon dioxide contents. A regression equation was determined for correcting the volume of expired air as measured the volume meter.

Estimation of Body Density and Body Fat

Basically derived from Archimedes principle of buoyancy, the hydro-

static method of estimating body density was completed for each subject. The values of fat free body weight for each subject were obtained from an associated study by Neill (32).

A large galvanized steel plate tank, 72 inches in height and 48 inches in diameter, was used for the underwater weighing. During the weighing, the subject supported a 17.5 pound underwater weight on his lap while seated in an aluminum chair and submerged in the tank. The chair was suspended from the ceiling and attached to a voltage regulated load cell which provided an electrical signal to be amplified on an adjoining Sargent recorder.

Procedure

1. The Sargent recorder was calibrated to give a reading of zero for the weight of the chair and supporting cable underwater.

2. Dressed in a nylon swim suit, the subject was weighed on land.

3. With the subject seated submerged to his neck in the tank and supporting the weight, vital capacity was measured using a Collin's spirometer.

4. Air bubbles were brushed from the subject's body.

5. After maximum inspiration, the subject lowered his head approximately 12 inches into the tank, brushed air bubbles from his hair, and remained in a relaxed motionless state until signalled to emerge.

6. This procedure is repeated three times and the lowest reading from the Sargent recorder is used in the calculation of body density.

7. The water temperature, room temperature, and barometric pressure were recorded.

Formulae

Corrected for residual volume, vital capacity, and gastro-intestinal gas volume, the formula used for calculating body density was:

$$D_b = \frac{M_a}{M_a - M_w - 0.0362(TVG)} \times D_w$$

where D_b is the density of the body

M_a is the weight of the body in air

M_w is the apparent weight of the body in water

D_w is the relative density of the water

TVG is the total volume of gas in the body

and 0.0362 is the weight supported by one cubic inch of air at BTPS.

The formula described by Brozek et al (11) was used for the calculation of body fat. Body density values calculated from above were substituted into the formula:

$$F_b = \frac{4.570}{D_b} - 4.142$$

where F_b is total body fat expressed as a fraction of unity and D_b is the density of the body.

Mitchell, Sproule, and Chapman Treadmill Test

Only slight alterations to reduce the length of testing time were made regarding the procedure of this test originally designed by Mitchell, Sproule, and Chapman (28).

Prior to each two-and-one-half-minute run, the subject was connected to an adjustable open-close Douglas bag circuit by means of a four flap triple-J valve and mouthpiece. During the last minute of the prescribed run at six miles an hour, the expired gas sample was collected. Analysis

of the gas occurred during the ten minute recovery period following each run. The males began at a 7.5 percent grade, and the females began at a zero percent grade. The grade was increased 2.5 percent for both sexes for each successive run.

The procedure was as follows:

1. The subject performed a ten minute warm-up at three miles per hour at a ten percent grade.

2. A ten minute rest followed.

3. The subject ran at six miles per hour for two-and-one-half minutes. Expired air was collected during the last minute of the run.

4. A ten minute rest followed during which the expired air sample was analyzed.

5. The work was increased by raising the grade of the treadmill by 2.5 percent and another two-and-one-half minute run at six miles per hour was performed. Expired air was collected during the last minute and analyzed during the following ten minute rest.

6. The grade of the treadmill was increased 2.5 percent again and another run was attempted. This procedure was repeated until oxygen consumption on two successive runs declined or increased less than 54 milliliters of oxygen as described by Mitchell, Sproule, and Chapman (28).

Modified Astrand Bicycle Ergometer Test

The actual testing procedure, as described by Astrand (4, 5), was performed on a Monark Bicycle Ergometer (45). Minor adjustments were made for both sexes regarding initial work loads and work increments. The seating height was adjusted until the knee cap of the subject was directly above the instep of the foot when the pedal was at the lowest

point. The electrodes from the VISO 100 Electrocardiogram were filled with Redux. In each case, the brake belt was adjusted from a resistance of zero to the required resistance as soon as pedaling began. The subject was required to pedal at 50 revolutions per minute which was paced and recorded by an electric metranome. The subject worked against three progressively increasing work loads for four-minute trials. While the analysis of expired air taken during the last minute of each trial was completed, the subject gained a five minute rest.

Testing proceeded as follows:

1. Each male subject performed a four minute warm-up ride at 450 kpm. The female work load as 150 kpm for the warm-up bout.

2. A five minute rest followed.

3. The males performed the initial test ride at a 750 kpm work load. The females work load was 450 kpm. After two minutes and forty-five seconds of the ride, the gas collecting apparatus was connected to the subject. Expired air was collected during the last minute of the ride. Heart rate and pedal revolution were recorded immediately after the exercise bout.

4. During the five minute rest, the gas sample was analyzed.

5. The work load of each subsequent exercise trial was increased by 150 kpm for both male and female subjects.

6. This procedure was repeated until the maximal oxygen consumption on two successive rides declined or increased less than 80 milliliters of oxygen, as described by Astrand (4).

In the case of both the Mitchell, Sproule, and Chapman test and the modified Astrand test, if the subject was unable to complete the last work load attempted, the partial Douglas bag was corrected appropriately

to approximate a full minute collection of expired air.

Modified Sjostrand Physical Work Capacity 170 Test

First described by Sjostrand (40), this test has been altered to accommodate ease of administration and individual differences among subjects. Ergometer adjustments and electrocardiogram arrangements were similar to those made with each subject for the Astrand test. However, the pedal frequency for this test was 60 complete revolutions per minute.

The testing procedure was as follows:

1. The subject was required to complete a 12 minute exercise bout consisting of three, four minute increasing difficult work rates.

2. The male subjects began at an 750 kpm work load and the females began at a 450 kpm work load.

3. The second and third work load increments were adjusted depending on the heart rate responses at the third and seventh minute of the test. The work loads were adjusted in an attempt to elicit three steady states of heart rate within the ranges 115-130, 135-155, and 160-180 beats per minute for each subject.

4. The heart rates were plotted against work loads and a work load necessary to produce a heart rate of 170 beats per minute were determined.

The subject's score was the work in kilopond meters that would produce a steady heart rate of 170 beats per minute.

Progressive Step Test

The Progressive Step test was designed to simulate principles and procedures of those described in the Sjostrand technique.

The apparatus consisted of three progressive step heights of 10, 25, and 40 centimeters respectively. Depending on the subject's response,

two sliding shelves of five centimeters each could add to the work load. The electrodes of the electrocardiogram were attached to each subject as described for previous tests. Pre-exercise heart rate was less than 100 beats per minute before testing proceeded.

Testing procedure was as follows:

1. The subject was required to complete three continuous four minute stepping exercise bouts at increasing height levels. Stepping rate was maintained at 28 steps per minute and was guided visually and audibly by an electric metranome.

2. Male subjects began at a stepping height of 25 centimeters and females began at a height of 15 centimeters.

3. Height increments at the completion of third and seventh minutes were adjusted according to the subject's heart rate response at these respective times. The heights in an attempt to elicit three steady states of heart rate within the range of 115-130, 135-155, and 160-180 beats per minute for each subject.

4. The fourth-minute heart rates and respective work loads of each level were plotted and the work load for a heart rate of 170 beats per minute was determined.

The subject's score was the work in kilogram meters that would produce a steady heart rate of 170 beats per minute.

Statistical Analysis

Accepting the Mitchell, Sproule, and Chapman test as the criterion measure of physical fitness, estimates of the validity of the Astrand, Sjostrand, and Progressive Step tests were investigated.

Reliability measures were examined using the test-retest method for

all the tests except the Astrand Bicycle Ergometer test and the body densitometry measure. Reliability and validity measures were determined using the Pearson product-moment correlation as outlined by Ferguson (18).

The method of testing the significance of the difference between two correlation coefficients for correlated samples as described by Ferguson (18) was also used. The resulting 't' distribution values of the compared correlation coefficients were all examined at the 0.05 level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

Characteristics of the Subjects

A random selection of twenty-four male and twenty-four female students, enrolled in the first-year undergraduate program in the Faculty of Physical Education, University of Alberta, comprised the sample of subjects used in this study. Admission to the first year University program is in conjunction with a successful medical examination. Some of the characteristics of the subjects are given in Table 4.1.

Table 4.1

Characteristics of the Subjects

	Mean	Standard Deviation	Range
Females			
Age (yrs)	18.67	0.63	17.92 - 20.42
Height (ins)	65.28	2.10	60.50 - 68.50
Weight (kg)	59.24	5.87	48.65 - 68.27
Fat (%)	23.43	4.46	18.30 - 33.45
Fat Free Wt (kg)	45.17	5.38	36.04 - 59.31
Males			
Age (yrs)	19.97	1.16	18.33 - 22.42
Height (ins)	70.59	2.39	65.50 - 75.00
Weight (kg)	76.10	8.80	59.42 - 92.53
Fat (%)	12.74	4.32	5.25 - 21.76
Fat Free Wt (kg)	66.15	8.57	49.29 - 80.42

Mean Scores of Test Results

The mean of each test, combined or overall mean when the test was repeated, and the respective standard deviations are presented in Table 4.2.

Maximal Oxygen Uptake Tests MVo_2

Initially assigned the criterion Mitchell, Sproule, and Chapman

Table 4.2

Mean Scores of the Test Results

TEST	TEST 1		TEST 2		MEAN OF TESTS 1 & 2	
	Male	Female	Male	Female	Male	Female
MITCHELL, SPROULE, & CHAPMAN						
1./min	3.90	2.31	3.94	2.33	3.92	2.32
	.55	.44	.65	.41	.58	.41
ml/kg/min	51.48	39.00	51.85	39.12	51.71	39.06
	5.37	6.02	5.56	4.87	5.13	5.05
ml/kg ffr/min	59.32	50.31	59.57	50.39	59.41	50.35
	6.11	8.27	6.32	4.97	5.86	5.97
ASTRAND						
1./min	3.52	2.12				
	.61	.41				
ml/kg/min	46.47	35.67				
	6.25	5.59				
ml/kg ffr/min	53.32	43.83				
	6.45	6.50				
PROGRESSIVE STEP						
kgm/min	885.79	496.08	855.62	489.87	870.67	488.17
	186.20	115.45	190.66	118.85	180.15	109.84
kgm/kg/min (or m/min)	11.66	8.21	11.27	8.22	11.47	8.23
	1.87	1.51	2.17	1.72	1.88	1.57
kgm/kg ffr/min	13.44	10.11	13.00	10.09	13.22	10.10
	2.28	1.73	2.62	1.67	2.31	1.81
SJOSTRAND						
kpm/min	1366.71	765.04	1323.50	773.50	1345.08	769.42
	300.07	167.25	251.56	171.33	269.40	158.23
kpm/kg/min (or m/min)	18.03	12.91	17.47	13.03	17.75	12.97
	3.42	2.51	2.87	2.40	3.04	2.26
kpm/kg ffr/min	20.74	15.84	20.08	15.98	20.41	15.91
	4.04	2.84	3.30	2.67	3.56	2.50

Treadmill test, the remaining tests, which included a repeat of the above test, were assigned in random order to each subject. The mean results were reported in absolute values as liters of oxygen per minute (1./min), milliliters per kilogram of total body weight per minute (ml/kg/min), and finally milliliters per kilogram of fat free body weight per minute (ml/kg ffr/min). The values were reported for both male and female subjects.

Although each subject competed only one trial of the modified Astrand Bicycle Ergometer test, the results were expressed in the same units as stated above.

Both sexes demonstrated higher mean maximal oxygen uptake values for the Mitchell, Sproule, and Chapman test as opposed to the modified Astrand test. Comparing the initial maximal oxygen uptake values on the Mitchell, Sproule, and Chapman test to those obtained on the Astrand Bicycle test, the male mean values were 3.90 and 3.52 1./min, respectively. These results demonstrated that maximal oxygen uptake values as determined by the treadmill technique were approximately 10 percent greater for males and 12.5 percent greater for females when compared to the values determined by the bicycle test. It is interesting to note that this difference is in accordance with the findings of Glassford et al (21), who found a maximal oxygen uptake of 3.752 1./min on the Mitchell, Sproule, and Chapman test and 3.485 1./min on the Astrand test for a group of male subjects. Astrand and Saltin (7) also reported similar differences between the maximal oxygen uptake values as determined for several adult subjects using the treadmill and bicycle ergometers. The values obtained were 4.69 1./min and 4.47 1./min, respectively, for the two techniques. This difference between MVo_2 values may be partly attributable to the difference

in muscle mass and posture required for each exercise. Basically the Mitchell, Sproule, and Chapman Treadmill test demands an overall running effort, whereas the Astrand Bicycle test requires a more localized leg power effort.

Physical Work Capacity 170 Tests

Each subject completed two trials of the modified Sjostrand Physical Work Capacity 170 Test. The subject's score was interpreted as the work in kilopond meters (kpm) that he would be able to produce at a heart rate of 170 beats per minute. The results are expressed in kilopond meters per minute (kpm/min), kilopond meters per kilogram of body weight per minute which is the same as meters per minute (kpm/kg/min or m/min), and kilopond meters per kilogram of fat free body weight per minute (kgm/kg ffr/min). In each test-retest situation for the work capacity tests, the repeated trials followed each other within a minimum period of twenty-four hours.

Each subject also completed two trials of the Progressive Step test. An individual's score was interpreted as the work in kilogram meters that he would be able to perform at a heart rate of 170 beats per minute. Table 4.2 expresses the results of the Progressive Step test in kilogram meters per minute (kgm/min), kilogram meters per kilogram of body weight per minute (kgm/kg/min or m/min), and kilogram meters per kilogram of fat free body weight per minute (kgm/kg ffr/min).

The mean Physical Work Capacity 170 results for males on the Sjostrand test was 1345 kpm/min and 769 kpm/min for the females. These scores are substantially higher than the comparative step test means of 870 kgm/min and 488 kgm/min respectively. As Shephard (38) and Nagle et al (31) have

illustrated, up to one-third of the work can occur during the descent in stepping procedures. This work was not calculated in this study, therefore it was understandable that the higher scores should result from the Sjostrand test.

Cumming (15) presented comparative Physical Work Capacity tables for various groups of men and women in the 18 to 40 years of age range. The mean work capacity score of 1345 kpm for the physical education student males in this study appeared higher than the scores reported for 'average' men in Cumming's study. Similarly, the mean score for females in this study was superior to that of 515 kpm found for Winnipeg nurses, however, it was lower than 840 and 835 kpm reported for Stockholm nurses and medical students, respectively. The popularity of bicycle riding in Sweden as compared to Canada may explain some of the differences in the observed scores. The Canadian Association for Health, Physical Education, and Recreation Work Capacity Study (24) reported PWC_{170} values of 873.8 ± 224.5 and 476.7 ± 147.3 kpm for 17 year old male and female students randomly selected from the school population in Canada. The work capacity scores of the Physical Education students in this study, who are generally one-and-one-half years older, appear substantially greater than the scores obtained for the sample of 17 year old students of the general school population.

Reliability of the Tests

Test-retest reliability coefficients of the tests are presented in Table 4.3. As the Astrand test was not repeated, a reliability coefficient was not available. The retest situations for the modified Sjostrand and Progressive Step tests were completed on the first day following the

initial test. The Mitchell, Sproule, and Chapman retest situation was allotted randomly in the seven-test sequence for each of the forty-eight subjects.

Table 4.3

Reliability of the Tests

Test	Male	Female	
Mitchell, Sproule, Chapman	.88	.83	1./min
Modified Sjostrand	.91	.75	kpm/min
Progressive Step	.83	.82	kgm/min
Mitchell, Sproule, Chapman	.77	.71	ml/kg/min
Modified Sjostrand	.87	.70	kpm/kg/min
Progressive Step	.74	.86	kgm/kg/min
Mitchell, Sproule, Chapman	.75	.72	ml/kg ffr/min
Modified Sjostrand	.57	.66	kpm/kg ffr/min
Progressive Step	.46	.72	kgm/kg ffr/min

Table 4.3 lists the reliability coefficients in three separate categories. The coefficients appear highest when reported in absolute units (1./min, kpm/min, and kgm/min). When body weight was kept constant, the coefficients tended to diminish. Upon division by fat free body weight the reliability coefficients appeared lowest.

The lowering of the reliability coefficients by keeping body weight and fat free body weight constant indicated the influence these factors have upon oxygen consumption and work capacity values. That is, body weight tends to be a factor or variable which keeps the reliability coefficient high. Larger persons appeared to score higher, whereas, smaller persons generally acquired lower scores on the tests. However, the reported

coefficients for this data indicated that the administration of repeated testing was reliable. A pilot study indicated that body densitometry scores were also reliable.

Corrections for Attenuation

The effects of errors of measurement tend to reduce the size of the correlation coefficient. That is, the correlation between true scores will tend to be greater than the correlation between observed scores. Table 4.4 illustrates the correlations between observed scores and true scores for the Sjostrand and Progressive Step tests for the males and females. The symbol r_{xy}, where r symbolizes the correlation coefficient, represents the original correlation between the initial Sjostrand and Progressive Step tests (see Tables 4.7, 4.9, 4.11 and 4.8, 4.10, 4.12 for males and females, respectively). The symbol r_{TxTy} represents the true correlation between the two tests after the correction for attenuation has been made.

Table 4.4

Corrected Correlations for Sjostrand and Step Tests

Male		Female		
r_{xy}	r_{TxTy}	r_{xy}	r_{TxTy}	
.64	.74	.72	.92	kpm and kgm/min
.50	.62	.67	.86	kpm and kgm/kg/min
.45	.88	.54	.78	kpm and kgm/kg ffr/min

In each of the above cases, the correction for attenuation has been calculated as illustrated in Ferguson (18). As an example, when the correlation coefficients have been determined from scores in their

absolute units (kpm/min and kgm/min), the difference between the observed and true correlations for the males indicates that the presence of measurement error has resulted in approximately a 14 percent loss in predictive capacity between the two tests.

Example: $r_{xy}^{2} \times 100$

$r_{xy}^{2} \times 100 = .64^{2} \times 100 = 40.96\%$

$r_{TxTy} - 100 = .74^{2} \times 100 = 54.76\%$

where r_{xy} is the observed correlation from absolute units between initial Sjostrand and Step tests for males and r_{TxTy} is the corrected correlation between the initial Sjostrand and Step tests for the males.

The difference between the two correlations is approximately 14 percent.

Stated somewhat differently, the variance interpretation of the correlation of the absolute units or observed values reveals that approximately 41 percent of the variance of the Sjostrand test can be attributed to variance in the Step test. However, after correcting for attenuation approximately 55 percent of the variance of the Sjostrand is accountable by variance in the Progressive Step test and 45 percent still attributable to other factors or variables which exist in a non-predictive capacity.

Partial Correlations

Table 4.5 represents the correlations of all the test variables with kilograms of body weight and with fat free kilograms of body weight for the males and females in this study. It is apparent that body weight and fat free body weight correlate fairly well when the test variables are expressed in absolute units, and that the values decrease when the correlations are expressed per kilogram body weight or per kilogram fat free body weight.

Table 4.5

Correlations Between Body Weight and Between Fat Free Body Weight and All Test Variables

TEST VARIABLES	Males Body Weight	Males Fat Free Body Wt	Females Body Weight	Females Fat Free Body Wt
MSC 1 l/min	0.65	0.70	0.60	0.62
2	0.74	0.76	0.72	0.83
$\bar{X}$	0.72	0.76	0.69	0.76
MSC 1 ml/kg/min	-0.17	-0.02	0.13	0.25
2	0.08	0.20	0.27	0.53
$\bar{X}$	-0.04	0.10	0.22	0.41
MSC 1 ml/kg ffr	-0.24	-0.28	0.04	-0.10
2 /min	0.03	-0.06	0.14	0.08
$\bar{X}$	-0.10	-0.18	0.21	0.16
ASTR l/min	0.60	0.69	0.59	0.62
ml/kg/min	-0.04	0.14	0.15	0.27
ml/kg ffr /min	-0.08	-0.06	0.13	0.03
STEP 1 kgm/min	0.63	0.57	0.39	0.57
2	0.53	0.48	0.47	0.54
$\bar{X}$	0.61	0.55	0.52	0.63
STEP 1 kgm/kg/min or m/min	0.09	0.09	0.13	0.35
2	0.03	0.03	0.10	0.24
$\bar{X}$	0.06	0.06	0.10	0.30
STEP 1 kgm/kg ffr /min	-0.01	-0.14	-0.07	0.52
2	0.03	-0.07	0.07	0.52
$\bar{X}$	0.04	-0.08	0.08	0.11
SJOS 1 kpm/min	0.48	0.49	0.44	0.59
2	0.52	0.53	0.55	0.67
$\bar{X}$	0.51	0.52	0.53	0.68
SJOS 1 kpm/kg/min or m/min	-0.03	0.03	0.01	0.25
2	-0.07	0.00	0.12	0.35
$\bar{X}$	-0.05	0.02	0.07	0.32
SJOS 1 kpm/kg ffr /min	-0.02	0.09	0.00	0.10
2	-0.36	-0.24	0.13	0.19
$\bar{X}$	-0.08	-0.13	0.07	0.15

It is interesting to note that the correlations between body composition and the maximal tests show a greater relationship with the Mitchell, Sproule, and Chapman Treadmill test than with the corresponding Astrand Bicycle Ergometer test. Similarly, at the submaximal level, the correlations between body composition and the Progressive Step test are greater than those between body composition and the modified Sjostrand bicycle ergometer test. Thus, it would seem that body composition has a greater influence on work performance if the work to be done involves the lifting and supporting of total body mass.

Table 4.6 illustrates the partial correlation coefficients between the second Mitchell, Sproule, and Chapman test and the Astrand test with the effects of body weight and fat free body weight partialled out respectively. In each case the formula as presented in Ferguson (18) was used.

Table 4.6

Partial Correlations Between MSC_2 and Astrand Test

	Observed Correlation Between MSC_2 and ASTR (Absolute Units)	Body Weight Partialled Out	Fat Free Body Weight Partialled Out
Males	.87	.79	.74
Females	.85	.76	.77

It is apparent that part of the correlation between the Mitchell, Sproule, and Chapman test and Astrand test occurs because both tests are also correlated with each of body weight and fat free body weight. The above correlations illustrate the change which occurs between the relationship of the two tests when the effect of body weight or fat free body weight is eliminated or removed.

Using a variance interpretation for the males as an example, it is originally noted that the proportion of overlap between the Mitchell, Sproule, and Chapman test and Astrand test is $.87^2$ or .7569 (see Table 4.7 for the correlation coefficient). The proportion of overlap with body weight partialled out is $.79^2$ or .6241 (see Table 4.6 for partial correlation coefficient). Thus, the proportion of overlap which results between the two maximal oxygen uptake tests due to the effect of body weight is .7569 - .6241 or .1328. It is also appropriate to state that the percentage of total association present resulting from the effect of body weight is .1328/.7569 x 100 or approximately 17.50 percent. The remaining 82.50 percent of the association between the two maximal oxygen uptake tests results from other factors.

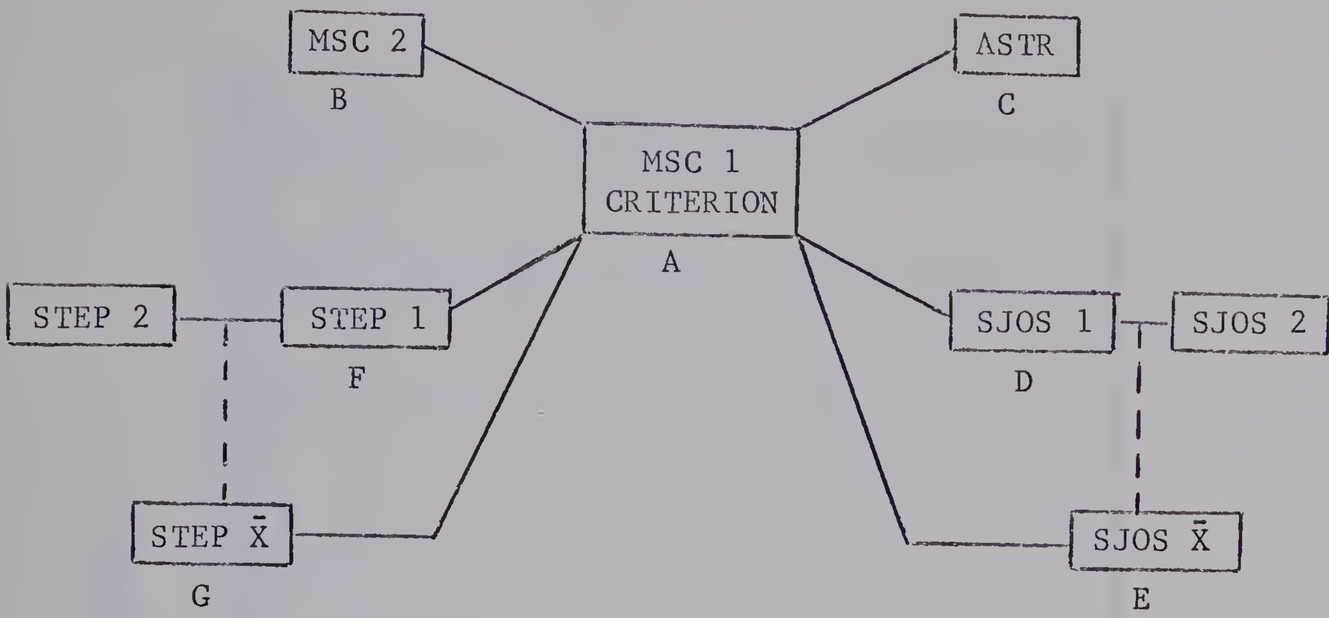
Interrelationships of Maximal Oxygen Uptake and Work Capacity

The main hypothesis of this study asserted that no significant differences existed between the correlation coefficients of the two maximal oxygen uptake tests and the correlation coefficients of the criterion Mitchell, Sproule, and Chapman test with the various combinations of the submaximal tests and their means (the Sjostrand and and Progressive Step tests). Tables 4.7 to 4.12, inclusive, represent the matrices for all test intercorrelations for males and females. The correlations were determined from absolute units, per kilogram of total body weight, and per kilogram of fat free body weight, respectively.

The following diagram, Figure 4.1, illustrated the intercorrelations that were investigated.

Figure 4.1

An Illustration of the Investigated Intercorrelations



The questions posed for both males and females took the following form: Is the correlation r_{AC}, between the criterion Mitchell, Sproule, and Chapman (MSC) and the Astrand (ASTR) maximal oxygen uptake tests significantly different than the correlation r_{AD}, between the criterion Mitchell, Sproule, and Chapman test and the initial Sjostrand work capacity test? If so, is the comparison still significantly different when r_{AC} and r_{AE} are considered, where r_{AE} is the correlation between the criterion Mitchell, Sproule, and Chapman test and the mean of the two Sjostrand (SJOS) tests. The same considerations were made regarding the Progressive Step test (STEP).

The 't' values resulting from the various correlation comparisons are summarized in Table 4.13. The significance between coefficients has been assessed in terms of 't' ratios as described in Ferguson (18). The correlations have been taken from the respective matrices, Tables 4.7 to 4.12.

Table 4.7

Correlation Matrix (l./min, kpm/min, and kgm/min)

Males

	MSC 1	MSC 2	MSC $\bar{X}$	ASTR	SJOS 1	SJOS 2	SJOS $\bar{X}$	STEP 1	STEP 2	STEP $\bar{X}$
MSC 1	---	.88	.96	.80	.54	.62	.59	.27	.31	.30
MSC 2		---	.98	.87	.54	.59	.58	.50	.41	.48
MSC $\bar{X}$			---	.86	.55	.62	.60	.41	.37	.41
ASTR				---	.56	.67	.62	.53	.49	.53
SJOS 1					---	.91	.98	.64	.76	.73
SJOS 2						---	.97	.67	.71	.72
SJOS $\bar{X}$							---	.67	.75	.74
STEP 1								---	.83	.95
STEP 2									---	.96

Table 4.8

Correlation Matrix (l./min, kpm/min, and kgm/min)

Females

	MSC 1	MSC 2	MSC $\bar{X}$	ASTR	SJOS 1	SJOS 2	SJOS $\bar{X}$	STEP 1	STEP 2	STEP $\bar{X}$
MSC 1	---	.83	.96	.87	.55	.45	.54	.35	.47	.51
MSC 2		---	.95	.85	.66	.60	.68	.48	.53	.59
MSC $\bar{X}$			---	.90	.63	.55	.63	.43	.52	.57
ASTR				---	.62	.55	.63	.54	.45	.48
SJOS 1					---	.75	.93	.72	.77	.79
SJOS 2						---	.94	.77	.76	.80
SJOS $\bar{X}$							---	.80	.82	.85
STEP 1								---	.82	.92
STEP 2									---	.96

Table 4.9

Correlation Matrix (per body weight: ml/kg/min, kpm/kg/min, kgm/kg/min, or m/min)

Males

	MSC 1	MSC 2	MSC $\bar{X}$	ASTR	SJOS 1	SJOS 2	SJOS $\bar{X}$	STEP 1	STEP 2	STEP $\bar{X}$
MSC 1	---	.77	.94	.68	.35	.46	.41	-.20	-.01	-.14
MSC 2		---	.94	.76	.30	.33	.32	.03	-.02	.00
MSC $\bar{X}$			---	.77	.34	.42	.39	-.10	-.04	-.07
ASTR				---	.39	.54	.47	.25	.24	.26
SJOS 1					---	.87	.97	.50	.68	.64
SJOS 2						---	.96	.53	.61	.62
SJOS $\bar{X}$							---	.53	.67	.65
STEP 1								---	.74	.92
STEP 2									---	.94

Table 4.10

Correlation Matrix (per body weight: ml/kg/min, kpm/kg/min, kgm/kg/min, or m/min)

Females

	MSC 1	MSC 2	MSC $\bar{X}$	ASTR	SJOS 1	SJOS 2	SJOS $\bar{X}$	STEP 1	STEP 2	STEP $\bar{X}$
MSC 1	---	.71	.94	.80	.38	.20	.31	.24	.27	.26
MSC 2		---	.91	.76	.53	.39	.50	.37	.31	.35
MSC $\bar{X}$			---	.84	.32	.31	.32	.48	.30	.40
ASTR				---	.50	.38	.48	.35	.30	.33
SJOS 1					---	.70	.92	.67	.70	.71
SJOS 2						---	.92	.70	.69	.73
SJOS $\bar{X}$							---	.74	.76	.78
STEP 1								---	.86	.96
STEP 2									---	.97

Table 4.11

Correlation Matrix (per fat free body weight: ml/kg ffr/min kpm/kg ffr/min, and kgm/kg ffr/min)

Males

	MSC 1	MSC 2	MSC $\bar{X}$	ASTR	SJOS 1	SJOS 2	SJOS $\bar{X}$	STEP 1	STEP 2	STEP $\bar{X}$
MSC 1	---	.75	.93	.63	.15	.55	.39	-.03	-.06	-.12
MSC 2		---	.94	.72	.12	.17	.33	.02	.03	.05
MSC $\bar{X}$			---	.72	.16	.39	.39	.00	.00	-.03
ASTR				---	.32	.37	.46	.12	.26	.26
SJOS 1					---	.57	.76	.45	.57	.60
SJOS 2						---	.71	.09	.31	.20
SJOS $\bar{X}$							---	.38	.69	.66
STEP 1								---	.46	.67
STEP 2									---	.94

Table 4.12

Correlation Matrix (per fat free body weight: ml/kg ffr/min kpm/kg ffr/min, and kgm/kg ffr/min)

Females

	MSC 1	MSC 2	MSC $\bar{X}$	ASTR	SJOS 1	SJOS 2	SJOS $\bar{X}$	STEP 1	STEP 2	STEP $\bar{X}$
MSC 1	---	.72	.76	.62	.20	-.06	.08	-.09	.18	.15
MSC 2		---	.61	.47	.28	-.07	.15	.04	.19	.15
MSC $\bar{X}$			---	.82	.34	.12	.27	.00	.24	.23
ASTR				---	.34	.25	.36	.11	.21	.24
SJOS 1					---	.66	.90	.54	.65	.63
SJOS 2						---	.90	.62	.64	.66
SJOS $\bar{X}$							---	.65	.73	.74
STEP 1								---	.72	.86
STEP 2									---	.95

Table 4.13

Summary of 't' Ratios for Correlation Coefficient Comparisons

CRITERION MITCHELL, SPROULE, CHAPMAN and ASTR (r_{AC})	Males			Females		
	Absolute Units	Per Body Wt	Per Fat Free Wt	Absolute Units	Per Body Wt	Per Fat Free Wt
MSC 1 & SJOS 1	* L	NS	* L	** L	** L	* L
MSC 1 & STEP 1	** L	** L	** L	** L	** L	** L
MSC 1 & SJOS $\bar{X}$	NS	NS	NS	** L	** L	** L
MSC 1 & STEP $\bar{X}$	** L	** L	** L	** L	** L	* L

where * indicates 0.05 level of significance

and ** indicates 0.01 level of significance

As an example, the initial '*L' symbols as shown in Table 4.13 indicate that the difference between the correlation coefficients .80, for the MSC 1 and ASTR, and .54 for the MSC 1 and SJOS 1, for the males is significant at the 0.05 level of significance and that the latter correlation, between the maximal and submaximal test, is 'lower' than the correlation between the two maximal oxygen uptake tests. These correlations have been determined from scores in absolute units. The above table also reports the results per kilogram of total body weight and per kilogram of fat free body weight. The symbols '**' indicate significance at the 0.01 level of significance.

All values of 't' for the females appeared significant at the 0.01 level of significance except for two cases when the coefficients were determined from scores expressed per fat free body weight. However, for both comparisons, which involved the MSC 1 and SJOS 1, and the MSC 1 and STEP $\bar{X}$ correlation coefficients against the correlation between the two maximal tests, the values of 't' showed significant differences at the 0.05 level of significance. Thus, for the females tested, neither the modified Sjostrand nor the Progressive Step tests appeared as valid predictors or indicators of physical fitness as did the modified Astrand test, when the Mitchell, Sproule, and Chapman Treadmill test was considered the criterion measure of fitness.

For the males all the values of 't' were significantly different at the 0.05 level of significance when the correlations were calculated from absolute units, except in the case where the mean of the two Sjostrand tests and the criterion test were correlated and compared to the two maximal oxygen uptake tests. This value of 't', 1.878 (see Appendix B), was slightly lower than the critical value 't' of 2.080. However, it was

noted that none of the 't' values for this comparison were significant at the 0.05 level of significance, regardless whether the correlation was determined from scores in absolute units, per body weight, or per fat free body weight. As with the females, when the correlation between the MSC 1 and STEP test was compared to the correlation between the MSC 1 and ASTR test, the difference was significant at the 0.01 level of significance.

Where the probability is less than 0.01 in all but one case, the significance of the comparisons, between the MSC 1 and STEP correlations and MSC 1 and ASTR correlations, were essentially the same for both males and females. The results were not as conclusive when considering the comparisons of the MSC 1 and SJOS correlations with the respective MSC 1 and ASTR correlations for the males. It is interesting to note the consistency of non-significance demonstrated when the mean of the Sjostrand tests is considered in the above comparison. Therefore, excluding the possibility that repetition of the Sjostrand test may be a valid predictor of fitness for the males, the results demonstrated in the remainder of the cases, that the submaximal tests used were not as valid predictors of physical fitness for either sex as was another maximal oxygen uptake test, the Astrand Bicycle Ergometer test, when the Mitchell, Sproule, and Chapman Treadmill test was used as the criterion measure of fitness.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

It was the purpose of this study to investigate the interrelationships between maximal oxygen uptake values and work capacity values. The main hypothesis asserted that no significant differences existed between the correlation of two maximal tests and the correlation of a criterion maximal oxygen uptake test with a submaximal work capacity test. On the basis that this main hypothesis was not accepted, the subsidiary problem investigated the interrelationship when the mean of two submaximal trials was correlated with the criterion. The criterion measure of physical fitness in this study was the Mitchell, Sproule, and Chapman Treadmill test. The other test of maximal oxygen uptake was the modified Astrand Bicycle Ergometer test and the submaximal tests included repeated performances on the modified Sjostrand Bicycle Ergometer and Progressive Step tests.

The subjects, twenty-four male and twenty-four female, were selected at random from the enrollment of students in the first-year program in the Faculty of Physical Education, University of Alberta, 1967-68. All subjects were tested for (a) maximal oxygen uptake, (b) physical work capacity 170, and (c) body composition using a densitometric method, as outlined by Neill (32). Scores were available in absolute units, per kilogram of total body weight, and per kilogram of fat free body weight. Test-retest reliabilities were determined for the Mitchell, Sproule, and Chapman, the Sjostrand, and the Progressive Step tests. Each subject completed the testing within a three-week period with at least two days between maximal oxygen uptake tests.

The reliability and validity coefficients were all determined employing the Pearson product-moment correlation technique as described by Ferguson (18). This source was also consulted for further appropriate statistical analysis necessary to interpret the data.

Conclusions

Within the limitations of this study, the following conclusions were made:

1. For the female subjects there was a significant difference at the 0.01 level of significance between the correlation coefficient of the criterion Mitchell, Sproule, and Chapman test and the modified Astrand test, and the correlation of this criterion test with either of the submaximal tests or their means, except when expressed in fat free body weight using the initial Sjostrand trial or the mean of the Step test trials. In these latter comparisons these differences were supported at the 0.05 level of significance.

2. For the male subjects there was a significant difference at the 0.01 level of significance between the correlation coefficient of the two maximal oxygen uptake tests and the correlation of the criterion maximal test with either the initial Step test trial or the mean of the repeated trials.

Using the correlation of the initial Sjostrand test with the criterion test as the comparison to the correlation between the two maximal tests, the results were significant at the 0.05 level of significance, except when expressed per kilogram of total body weight, the comparison was non-significant.

In all cases, the comparison between the correlation coefficients of the mean of the Sjostrand trials with the criterion maximal test and

the two maximal tests revealed a non-significant difference.

General Conclusion

On the basis of these findings, it was apparent that neither the modified Sjostrand nor the Progressive Step test for the females, nor the Progressive Step test for the males, was as valid a predictor of physical fitness as was another maximal oxygen uptake test, the modified Astrand Bicycle Ergometer test, when the Mitchell, Sproule, and Chapman Treadmill test was used as the criterion measure of fitness. However, the evidence appeared less conclusive in this respect for the males when considering the modified Sjostrand test as a valid predictor of fitness.

Recommendations

A revision of the Progressive Step test procedures could be investigated in light of supplementing its capacity in measuring physical work capacity 170 in relation to the modified Sjostrand test.

A further investigation could examine the trend or possibility of the Sjostrand test as a valid predictor of physical fitness for the males or the difference that may exist between the sexes in this respect, when maximal oxygen uptake is chosen as the criterion measure of fitness.

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APPENDICES

APPENDIX A

STATISTICAL PROCEDURES AND SAMPLE CALCULATION SHEETS

Correlation Coefficients

The IBM System 360/67 APL programme SCORR was used to calculate the correlation coefficients between the various tests and variables. This programme computes a correlation coefficient matrix using the Pearson product-moment correlation as described in Ferguson (18:111).

$$r = \frac{N\Sigma XY - \Sigma X\Sigma Y}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2]\ [N\Sigma Y^2 - (\Sigma Y)^2]}}$$

where r is the simple correlation coefficient between X and Y

X is the sum of the X values

Y is the sum of the Y values

N is the number of observations.

Correction for Attenuation

Errors of measurement tend to attenuate the correlation coefficient between obtained scores from the correlation between true secores. The following formula from Ferguson (18:382) was used as the correction for attenuation.

$$r_{TXTY} = \frac{r_{XY}}{\sqrt{r_{XX}r_{YY}}}$$

where r_{TXTY} is the correlation between true scores

r_{XX} is the reliability of test X

r_{YY} is the reliability of test Y.

Parial Correlations

The first order partial correlation coefficient formula as shown in Ferguson (18:389) was used to interpret a portion of the data.

$$r_{XY.Z} = \frac{r_{XY} - r_{XZ}r_{YZ}}{\sqrt{(1 - r_{XZ}^2)\ (1 - r_{YZ}^2)}}$$

where $r_{XY.Z}$ is the correlation between residuals when Z has been removed from X and Y

r_{XY} is the correlation between variables X and Y
r_{XZ} is the correlation between variables X and Z
and r_{YZ} is the correlation between variables Y and Z.

Significance of the Difference Between Two Correlation Coefficients for Correlated Samples

The difference bewteen two correlation coefficients for correlated samples was tested by calculating a value 't' as described in Ferguson (18:189). The following expression follows the distribution of t with N - 3 degrees of freedom.

$$t = \frac{(r_{XY} - r_{XZ})\sqrt{(N - 3)(1 + r_{YZ})}}{\sqrt{2(1 - r_{XY}^2 - r_{XZ}^2 - r_{YZ} + 2r_{XY}r_{XZ}r_{YZ})}}$$

where r_{XY} is the correlation between variables X and Y
r_{XZ} is the correlation between variables X and Z
r_{YZ} is the correlation between variables Y and Z
and N is the number of subjects in the sample.

MITCHELL, SPROULE & CHAPMAN TEST

HEART RATE

NAME: ______________________________

DATE: ______________________

RESTING HEART RATE: ____________

TREADMILL % | HEART RATE

TREADMILL %	HEART RATE

MAXIMAL O_2 CONSUMPTION: ________________ l./min.

COMMENTS:

ASTRAND BICYCLE ERGOMETER TEST

NAME: ______________________________

DATE: ______________________________

RESTING HEART RATE: ______________

KPM	HEART RATE

MAXIMAL O_2 CONSUMPTION ______________ 1./min.

COMMENTS:

GAS ANALYSIS COMPUTATION

NAME: ____

DATE: ________________________________

TEMPERATURE: _________________________

BAROMETRIC PRESSURE: __________________

TREADMILL INCLINATION/BICYCLE LOAD: ___________________

$\% \; O_{2E} = . \_\_\_\_\_ \times 2.5 = \_\_\_\_\_ \%.$

$\% \; CO_{2E} = \_\_\_\_\_ \%.$

$\% \; N_{2E} = 100 - \_\_\_\_\_ \; \% \; O_{2E} - \_\_\_\_\_ \; \% \; CO_{2E} = \_\_\_\_\_ \%.$

$V_E ATPS + .982 \times \_\_\_\_\_ - .325 = \_\_\_\_\_$ 1./Min.

(partial to whole sample ATPS = _____ x _____ 1. = _____1./Min.)

V_E STPD = _____ (factor) x _____1./Min. = _____1./Min.

$V_I \text{ STPD} = \_\_\_\_\_ \; V_E \text{ STPD} \times \dfrac{\_\_\_\_\_ \; \% \; N2E}{79.04} = \_\_\_\_\_$ 1./Min.

$VO_2 = (\_\_\_\_\_ \; V_I \text{ STPD} \times .2093) - (\_\_\_\_\_ \; V_E \text{ STPD} \times . \_\_\_\_\_ \; O_{2E})$

= _____1./Min. Oxygen Uptake.

SJOSTRAND PWC_{170} TEST

NAME: ____

DATE: ____________________________

RESTING HEART RATE: ________________

	TIME								
	1		2		3		4		
WORK LOAD	HR	RPM	HR	RPM	HR	RPM	HR	RPM	STEADY STATE

ROOM TEMPERATURE: ________________

BAROMETRIC PRESSURE: ______________

COMMENTS:

PROGRESSIVE PWC_{170} STEP TEST

NAME: ______________________________

DATE: ________________

RESTING HEART RATE: __________

	TIME				
STEP HEIGHT	1	2	3	4	STEADY STATE

ROOM TEMPERATURE: ______________

BAROMETRIC PRESSURE: ____________

COMMENTS: ___________________

ESTIMATION OF BODY COMPOSITION

NAME: ____

DATE: ____________________________

MEASUREMENTS:

	POUNDS	LITERS	CUBIC INCHES
Weight in Air	______		
Vital Capacity (VC)		______	______
Residual Volume (RV)		______	______
Volume Gastro-Intestinal (VGI)			______
Weight in Water (full inspiration)	______		

CALCULATIONS:

Total Lung Capacity (TLC) = _____ (VC) + _____ (RV) + _____ (VGI)

= _____ TLC cu. in.

_____ TLC cu. in. x .0362 = _____ TLC lbs.

True Wt. = _____ (Wt. in Water) = _____ (TLC lbs.) = _____.

Body Volume = _____ (Wt. in Air) - _____ (True Wt.) = _____.

Body Density = _____ (Wt. in Air) / (_____ (Body Vol.) x _____ H_2O density)

= _____.

% Fat = $\frac{4.570}{\text{Body Density}}$ - 4.142 = _____%.

Lbs. Fat = _____ (% Fat) x _____ (Wt.) = _____ lbs.

Lbs. Fat Free = _____ (Wt.) - _____ (Lbs. Fat) = _____ lbs.

APPENDIX B

VALUES OF 't' RATIOS FOR

CORRELATION COEFFICIENT COMPARISONS

Values of 't' Ratios for

Correlation Coefficient Comparisons

Males

	Absolute Units	Per Body Weight	Per Fat Free Body Weight
MSC 1 & SJOS 1	2.154	1.882	2.435
MSC 1 & STEP 1	4.381	5.262	2.964
MSC 1 & SJOS $\bar{X}$	1.878	1.655	1.378
MSC 1 & STEP $\bar{X}$	4.061	4.711	3.390

where the critical values of 't' are:

2.080 for the 0.05 level of significance, and

2.831 for the 0.01 level of significance.

Values of 't' Ratios for

Correlation Coefficient Comparisons

Females

	Absolute Units	Per Body Weight	Per Fat Free Body Weight
MSC 1 & SJOS 1	3.413	4.592	2.125
MSC 1 & STEP 1	5.364	3.761	3.174
MSC 1 & SJOS $\bar{X}$	3.567	5.270	2.843
MSC 1 & STEP $\bar{X}$	3.359	4.907	2.227

where the critical values of 't' are:

2.080 for the 0.05 level of significance, and

2.831 for the 0.01 level of significance.

APPENDIX C

RAW SCORES

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST ONE - FEMALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
01	0	17.225	4.75	49.784	1.701
	2½	17.375	4.5	54.056	1.791
	5	17.575	4.5	60.990	1.905
	7½	17.775	4.15	69.080	2.003
	10	17.575	3.1	54.862	1.882
02	0	17.687	4.12	61.308	1.855
	2½	17.868	3.83	53.162	1.527
03	0	17.375	3.6	51.977	1.846
	2½				
	5	17.7	3.4	67.518	2.156
	7½	17.6	3.4	67.840	2.252
	10	17.65	3.0	66.552	2.238
04	0	16.975	3.0	51.199	2.158
	2½	17.125	3.4	57.149	2.240
	5	17.3	3.0	87.338	3.323
	7½	17.925	3.5	64.995	1.873
05	0	16.963	4.85	50.385	1.885
	2½	17.0	4.9	53.958	1.986
	5	17.275	5.05	62.182	2.048
	7½	17.55	4.8	72.982	2.198
06	0	17.625	3.0	56.166	1.906
	2½	17.8	2.8	63.792	2.058
	5	17.675	3.1	64.865	2.143

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
07	0	17.475	4.8	67.562	2.099
	2½	17.45	4.55	69.410	2.224
	5	17.512	4.6	71.499	2.225
08	0	17.785	4.4	58.126	1.640
	2½	17.588	4.25	60.853	1.893
	5	17.88	4.4	66.870	1.800
09	0	17.45	3.4	67.415	2.366
	2½	17.275	3.6	68.633	2.524
	5	17.375	3.6	76.832	2.728
	7½	17.425	3.4	83.241	2.947
	10	17.65	3.0	92.800	3.120
10	0	16.695	5.38	43.967	1.729
	2½	16.85	5.19	46.503	1.764
	5	16.625	5.29	52.474	2.126
	7½	16.85	5.0	61.145	2.351
	10	17.1	4.81	42.453	1.519
11	0	17.5	4.38	66.956	2.133
	2½	17.35	4.2	68.788	1.937
	5	17.65	4.4	76.085	2.276
	7½	18.75	4.3	81.220	1.321
12	0	16.85	3.4	46.037	1.965
	2½	16.975	3.4	48.873	2.009
	5	16.975	3.425	53.687	2.203
	7½	17.137	3.425	60.615	2.363
	10	17.575	2.8	60.756	2.133

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
13	0	17.894	4.81	60.298	1.555
	2½	17.35	4.71	62.973	2.071
	5	17.575	4.42	81.766	2.516
14	0	16.525	3.6	36.644	1.695
	2½	16.45	3.55	37.961	1.797
	5	16.525	3.75	51.158	2.346
	7½	17.0	3.6	51.398	2.069
15	0	16.287	4.1	37.166	1.782
	2½	15.938	4.35	34.586	1.788
	5	15.825	4.7	36.917	1.927
	7½	17.075	3.8	60.648	2.352
	10	18.138	2.8	86.445	2.419
	12½	17.8	2.1	71.520	2.439
16	0	18.27	3.8	51.401	1.217
	2½	18.52	3.0	64.490	1.419
17	0	16.763	5.05	35.403	1.396
	2½	15.575	5.4	41.104	2.200
	5	15.438	5.6	45.011	2.436
	7½	15.9	5.6	54.739	2.675
18	0	16.35	3.9	54.628	2.605
	2½	16.587	3.9	55.263	2.469
	5	16.7	3.8	56.533	2.560
	6½	17.0	4.0	86.763	3.401
	10	17.1	3.8	75.361	2.091

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
19	0	17.063	3.3	42.246	1.702
	2½	17.41	3.2	53.055	1.916
	5	17.650	3.1	60.493	2.018
	7½	17.75	2.9	68.465	2.224
20	0	18.162	4.0	69.919	1.712
	2½	18.025	3.9	74.091	1.963
	5	18.05	4.0	83.397	2.161
	7½	18.325	3.6	97.357	2.287
	10	18.237	2.8	82.113	2.194
21	0	15.913	4.3	48.921	2.451
	2½	15.458	4.5	42.172	2.420
	5	15.675	4.55	50.732	2.762
	7½	15.645	4.6	48.674	2.665
	10	16.513	4.2	66.219	2.969
22	0	17.775	5.0	59.699	2.050
	2½	18.1	4.3	71.632	1.754
	5	18.525	3.8	82.578	1.691
23	0	17.238	3.4	56.372	2.129
	2½	17.05	3.65	56.818	2.242
	5	17.3	3.6	64.080	2.336
	7½	17.6	3.3	74.624	2.497
	10	17.775	3.2	83.698	2.660
24	0	17.125	3.9	39.492	1.496
	2½	17.2	3.65	41.798	1.571
	5	17.687	3.35	47.764	1.539

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST ONE - MALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
25	7½	15.85	6.7	63.971	2.980
	10	15.92	6.7	70.410	3.218
	12½	16.237	6.4	84.357	3.584
	15	16.997	5.65	110.289	3.844
	17½	17.47	4.05	115.384	3.821
26	7½	15.975	6.7	62.591	2.817
	10	16.412	6.3	73.514	2.980
	12½	16.485	6.1	84.254	3.384
	15	18.328	5.85	100.866	1.766
27	7½	16.65	5.6	61.041	2.404
	10	16.775	5.2	64.179	2.494
	12½	17.225	4.8	79.397	2.717
	15	17.563	4.6	94.298	2.875
	17½	17.575	3.0	69.607	2.406
28	7½	16.3	5.8	74.858	3.240
	10	16.625	5.6	91.707	3.641
	12½	16.625	5.55	102.675	4.090
	15	16.84	5.25	104.833	3.974
	17½	17.15	3.39	118.012	4.592
29	7½	17.137	5.3	93.447	3.178
	10	17.375	4.9	109.471	3.511
	12½	17.325	4.85	112.370	3.690
	15	17.5	4.8	126.140	3.879
	17½	17.5	3.5	108.940	3.725
30	7½	16.05	4.7	81.001	3.998
	10	16.125	4.8	102.002	4.911
	12½	16.3	4.7	104.447	4.825
	15	16.664	4.7	114.482	4.800

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
31	7½	17.325	5.3	94.178	2.980
	10	17.525	4.85	103.945	3.150
	12½				
	15	17.3	4.6	99.860	3.376
32	7½	16.0	4.4	63.184	3.209
	10	16.4	4.0	74.518	3.486
	12½	16.95	3.8	91.772	3.704
	15	17.287	3.55	106.455	3.912
	17½	17.375	3.0	109.847	4.075
33	7½	16.087	4.4	64.456	3.202
	10	16.1	4.4	71.471	3.539
	12½	16.7	4.3	89.772	3.788
	15	17.2	3.75	106.057	3.976
	17½	17.4	3.4	115.733	3.394
34	7½	16.763	4.3	75.953	3.145
	10	17.45	3.8	103.102	3.509
	12½	18.063	3.0	129.729	3.667
35	7½	16.55	4.72	72.806	3.129
	10	16.587	4.56	85.413	3.665
	12½	16.788	4.4	87.882	3.585
36	7½	15.75	5.0	68.338	3.578
	10	16.025	4.8	79.913	3.948
	12½	16.825	4.0	109.184	4.521
	15	17.437	3.3	133.592	4.744

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
37	7½	16.737	5.35	94.299	3.672
	10	16.95	5.1	97.040	3.582
	12½	17.212	4.8	120.595	4.147
	15	17.525	4.3	130.327	4.139
38	7½	16.0	4.4	75.867	3.853
	10	16.25	4.35	84.448	4.033
	12½	16.7	4.2	101.965	4.329
	15	16.825	4.2	112.928	4.616
	17½	16.775	4.0	109.036	4.584
39	7½	16.162	6.6	72.423	3.107
	10	16.388	6.4	85.398	3.479
	12½	16.708	6.1	85.112	3.178
40	7½	15.625	4.9	58.726	3.183
	10	15.925	4.7	71.724	3.653
	12½	16.625	4.175	87.432	3.804
	15	16.925	3.6	91.419	3.767
41	7½	15.675	4.5	67.744	3.646
	10	15.312	4.6	63.187	3.725
	12½	15.637	4.5	72.100	3.973
	15	17.2	3.8	104.674	4.555
42	7½	16.687	5.8	71.828	2.757
	10	16.667	5.2	84.328	3.431
	12½	16.95	5.2	103.983	3.811
	15	17.375	4.8	112.257	3.630

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
43	7½	16.1	4.55	66.876	3.285
	10	15.975	4.6	72.130	3.648
	12½	16.762	4.1	92.334	3.872
	15	16.937	4.0	101.628	4.348
	17½	17.1	3.8	113.064	4.348
44	7½				
	10	17.05	6.6	77.104	2.442
	12½	16.025	7.0	76.015	3.313
	15	17.0	5.6	108.782	3.803
45	7½	16.325	4.9	58.221	2.642
	10	16.75	4.8	66.88	2.692
	12½	17.43	4.3	84.59	2.795
	15	18.05	3.8	99.74	2.639
46	7½	16.537	4.5	66.739	2.918
	10	17.2	3.8	84.355	3.138
	12½	17.413	3.55	94.712	3.331
	15	17.263	3.35	91.475	3.439
47	7½	16.7	3.85	85.192	3.696
	10	17.038	3.6	81.203	3.228
48	7½	16.4	4.35	77.948	3.574
	10	16.537	4.0	89.606	4.036
	12½	16.875	3.8	102.823	4.247
	15	17.3	3.6	115.548	4.213

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST TWO - FEMALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
01	0	17.325	4.65	46.133	1.539
	2½	17.575	4.5	53.364	1.633
	5	17.725	4.35	61.930	1.802
	7½	18.025	4.25	67.729	1.732
02	0	18.08	4.2	59.367	1.484
	2½	18.225	3.8	66.629	1.614
	5	18.375	3.75	73.793	1.658
03	0				
	2½	17.2	3.1	53.684	2.096
	5	17.375	3.2	61.546	2.251
	7½	17.65	3.1	65.313	2.179
04	0	16.825	3.425	46.493	1.996
	2½	16.683	3.575	47.238	2.094
	5	16.9	3.6	54.437	2.260
	7½	17.525	3.3	70.145	2.414
	10	17.888	2.95	83.773	2.576
05	0	17.45	3.7	66,101	2.267
	2½	17.2	3.8	60.781	2.261
	5	17.8	3.2	78.370	2.445
	7½	17.625	3.0	77.910	2.644
06	0	17.425	3.0	54.147	1.975
	2½	17.1	3.2	49.015	1.963
	5	17.488	3.2	64.452	2.265
	7½	17.75	3.1	73.908	2.372

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
07	0	17.475	4.75	67.133	2.095
	2½	17.45	4.675	66.972	2.142
	5	17.425	4.7	73.451	2.351
	7½	17.663	4.6	82.435	2.409
	10	17.875	4.1	85.934	2.394
08	0	17.45	4.2	50.780	1.674
	2½	17.4	4.05	55.093	1.873
	5	17.6	4.3	72.866	2.245
	7½	17.988	4.2	77.543	2.030
09	0	17.15	3.3	55.552	2.775
	2½	16.925	3.6	68.493	2.356
	5	17.05	3.3	64.982	2.626
	7½	17.125	3.65	71.705	2.764
	10	17.5	3.3	84.620	2.938
10	0	16.925	5.2	43.216	1.621
	2½	17.125	5.175	50.271	1.734
	5	17.063	5.2	51.223	1.804
	7½	17.4	5.1	61.905	1.933
	10	17.7	4.8	70.272	1.983
11	0	17.675	4.75	66.908	1.918
	2½	17.688	4.5	68.514	1.999
	5	17.725	4.8	76.942	2.147
	7½	17.713	4.8	83.391	2.340
12	0	16.375	3.85	38.333	1.821
	2½	16.7	3.5	42.104	1.866
	5	16.713	3.7	44.417	1.938
	7½	16.962	3.6	52.436	2.136
	10	17.275	3.1	60.390	2.301

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
13	0	16.95	5.5	56.104	2.012
	2½	17.775	5.1	61.360	1.625
	5	17.5	5.2	72.720	2.159
	7½	17.6	4.9	82.653	2.415
	10	18.1	4.0	96.260	2.434
14	0	17.263	3.05	46.520	1.786
	2½	17.388	2.8	54.045	2.025
	5	17.313	2.15	55.818	2.241
	7½	17.05	3.6	61.485	2.436
	10	17.85	2.9	80.273	2.517
16	0	17.725	4.55	52.172	1.490
	2½	18.025	4.0	59.731	1.567
	5	18.35	3.0	80.273	2.517
17	0	16.325	4.9	45.286	2.054
	2½	16.212	4.9	54.806	2.563
	5	16.512	5.0	54.401	2.324
18	0	16.638	3.45	47.440	2.146
	2½	16.763	3.4	56.341	2.467
	5	16.675	3.95	62.491	2.714
	7½	16.95	3.75	69.482	2.813
	10	17.425	3.75	84.816	2.925
	12½	17.625	2.3	83.876	3.002
15	0	15.925	4.2	32.772	1.713
	2½	16.35	3.9	42.684	2.035
	5	16.783	3.7	49.159	2.101
	7½	17.05	3.6	61.485	2.436
	10	17.85	2.9	80.273	2.517

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
19	0	17.25	3.1	42.529	1.634
	2½	17.3	3.1	50.965	1.926
	5	17.413	3.2	55.716	2.013
	7½	17.875	2.8	66.888	2.091
20	0	18.15	4.0	69.055	1.686
	2½	18.1	3.9	78.450	2.005
	5	18.3	3.9	88.282	2.032
	7½	18.338	3.8	92.182	2.102
21	0	15.075	4.3	34.920	2.191
	2½	17.469	4.3	36.086	1.172
	5	15.0	4.5	35.362	2.234
	7½	15.713	4.3	50.635	2.769
	10	16.563	3.9	67.581	3.041
	12½	17.375	3.1	88.218	3.249
22	0	17.062	5.8	61.226	2.059
	2½	17.337	5.5	73.712	2.282
	5	17.7	4.4	84.709	2.480
	7½	18.112	3.95	92.624	2.342
23	0	17.275	3.65	52.830	1.936
	2½	17.35	3.5	55.397	1.999
	5	18.338	2.9	79.980	2.116
	7½	18.187	3.1	81.793	2.172
24	0	17.213	3.75	43.120	1.603
	2½	17.55	3.3	50.447	1.720
	5	17.738	3.3	56.003	1.776

RAW SCORES - MITCHELL, SPROULE AND CHAPMAN TEST TWO - MALES

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
25	7½	15.337	7.2	57.292	2.965
	10	15.3	7.5	64.458	3.315
	12½	16.075	6.9	82.818	3.579
	15	16.725	6.8	109.713	
26	7½	16.032	7.2	63.929	2.677
	10	16.045	7.1	69.459	2.991
	12½	16.262	7.0	76.465	3.103
	15	16.95	6.6	95.063	3.132
27	7½				
	10	17.062	5.35	87.200	2.554
	12½	17.252	5.0	84.443	2.816
	15	17.65	4.55	92.949	2.744
28	7½	16.075	7.0	77.169	3.314
	10	16.075	6.6	82.170	3.616
	12½	16.4	6.4	95.395	3.855
	15	16.6	6.1	102.399	3.962
	17½	17.025	5.7	118.987	4.090
	20	17.15	4.7	118.012	4.183
	22½	16.375	4.6	85.381	3.882
29	7½	17.3	5.175	88.469	2.857
	10	17.2	4.9	89.306	3.062
	12½	17.65	4.8	109.041	3.146
	15	17.538	4.9	116.138	3.483
	17½	17.938	4.5	116.776	3.038
30	7½	16.1	4.4	82.621	4.339
	10	16.3	4.4	99.406	4.671
	12½	16.55	4.3	112.241	4.949
	15	16.925	4.1	129.353	5.158
	17½	17.05	4.0	142.834	5.508

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
31	7½	17.55	5.0	93.804	2.777
	10	17.525	4.8	106.227	3.233
	12½	17.812	4.5	113.695	3.140
32	7½	16.125	4.6	66.713	3.247
	10	16.6	4.0	84.267	3.729
	12½	16.85	4.0	93.528	3.843
	15	16.875	3.7	90.548	3.764
33	7½	16.525	4.3	65.364	2.898
	10	16.763	4.2	81.697	3.400
	12½	17.0	3.95	93.011	3.658
	15	17.4	3.7	109.981	3.842
	17½	17.313	3.4	110.544	3.897
34	7½	16.75	4.0	83.099	3.470
	10	17.113	3.7	92.184	3.555
	12½	17.775	3.1	117.329	3.728
	15	18.275	2.1	122.762	
35	7½	16.512	3.95	76.564	3.483
	10	16.837	3.9	84.243	3.497
	12½	16.7	3.95	83.844	3.615
	15	17.438	3.3	108.802	3.864
	17½	17.612	2.175	101.242	3.676
36	7½	16.188	4.5	77.878	3.750
	10	16.625	4.2	94.831	4.116
	12½	17.225	3.6	117.816	4.407
	15	17.325	3.25	131.689	4.882

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
37	7½	16.838	5.9	103.288	3.741
	10	17.138	5.1	119.563	4.130
	12½	17.5	4.6	134.539	4.209
	15	17.575	3.05	106.639	3.672
38	7½	16.525	4.0	85.295	3.856
	10	16.513	3.9	95.581	4.361
	12½	16.5	3.8	102.575	4.723
	15	16.7	4.0	108.747	4.675
39	7½	16.413	6.6	77.121	3.065
	10	16.475	6.35	85.772	3.398
	12½	17.18	5.5	104.327	3.427
40	7½	16.125	4.2	67.910	3.377
	10	15.963	4.6	74.080	3.758
	12½	16.4	4.2	89.001	4.117
	15	16.65	3.8	91.509	4.040
41	7½	16.526	4.25	74.492	3.317
	10	15.525	6.25	59.088	3.066
	12½	15.613	4.9	71.363	3.879
	15	16.288	4.55	85.804	4.009
	17½	17.025	3.7	114.437	4.540
42	7½	17.2	5.9	76.068	2.887
	10	17.025	5.5	96.994	3.386
	12½	17.125	5.2	104.793	3.609
	15	17.45	5.1	114.296	3.496
	17½	17.85	4.3	125.003	3.456

SUBJECT	% TREADMILL INCLINATION	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
43	7½	16.125	4.6	67.999	3.310
	10	16.763	4.05	89.36	3.759
	12½	17.125	4.1	98.121	3.665
	15	17.113	3.9	111.424	4.238
	17½	17.125	3.45	109.338	4.272
44	7½	15.5	7.5	62.021	3.032
	10	15.693	7.3	85.236	3.228
	12½	16.175	7.0	85.544	3.575
	15	16.688	6.2	94.543	3.528
45	7½	16.413	6.5	57.865	2.315
	10	16.288	6.4	62.835	2.630
	12½	16.731	5.8	74.625	2.823
	15	17.475	5.0	97.269	2.970
46	7½	16.7	4.0	71.043	3.044
	10	16.75	3.8	84.785	3.636
	12½	16.888	3.7	87.444	3.621
47	7½	16.7	3.7	85.966	3.764
	10	16.875	3.7	94.128	3.889
	12½	17.125	3.1	115.933	4.666
48	7½	16.438	4.2	77.654	3.555
	10	16.425	4.2	88.885	4.083
	12½	16.738	3.95	98.116	4.184
	15	17.163	3.6	116.256	4.441

RAW SCORES - ASTRAND MAXIMAL OXYGEN UPTAKE TEST - FEMALES

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
01	2.5	17.175	5.5	41.077	1.473
	3.0	17.2	5.3	53.638	1.782
	3.5	17.475	5.1	59.910	1.814
02	2.5	18.55	3.4	70.982	1.503
	3.0	18.45	3.3	66.136	1.502
03	2.5	17.675	3.2	58.094	1.904
	3.0	18.05	2.9	75.442	
	3.5	18.05	2.8	73,959	2.152
04	2.5	17.15	3.5	59.910	2.314
	3.0	17.125	3.6	46.745	1.805
	3.5	17.55	3.2	60.234	2.069
05	2.5	16.425	6.2	38.642	1.570
	3.0	16.95	5.9	54.836	1.908
	3.5	17.475	4.95	68.686	2.107
	4.0	17.675	4.25	71.899	2.157
06	2.5	17.138	3.4	41.995	1.640
	3.0	17.763	3.0	64.437	2.075
	3.5	18.125	2.55	76.227	2.196
07	2.5	17.25	5.1	45.025	1.491
	3.0	17.75	4.4	58.784	1.684
	3.5	18.6	3.7	82.364	1.627
08	2.5	17.875	4.5	52.138	1.397
	3.0	18.175	4.2	67.357	1.599
	3.5	18.225	3.8	69.225	1.677
	4.0	18.375	3.6	77.358	1.769

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
09	2.5	17.025	3.7	61.370	2.435
	3.0	16.863	3.75	45.301	1.884
	3.5	16.875	3.7	50.853	2.114
	4.0	17.275	3.5	65.948	2.443
	4.5	17.5	3.35	79.847	2.762
	5.0	17.625	3.1	84.425	2.843
10	2.5	17.612	5.0	59.611	1.717
	3.0	17.825	4.2	67.999	1.920
11	2.5	17.2	5.4	50.594	1.667
	3.0	18.125	4.0	82.424	2.058
	3.5	17.875	4.35	71.976	1.958
12	2.5	16.7	4.0	35.409	1.522
	3.0	17.325	3.4	51.305	1.881
	3.5	17.4	3.2	52.403	1.900
13	2.5	16.712	5.6	40.706	1.571
	3.0	17.15	5.3	54.082	1.831
	3.5	17.9	4.6	83.060	2.178
	4.0	18.262	3.8	93.738	2.228
14	2.5	16.725	3.8	34.091	1.473
	3.0	17.187	3.6	52.876	2.003
	3.5	17.125	3.6	53.595	2.073
15	2.5	16.9	3.9	40.677	1.657
	3.0	17.225	3.5	55.536	2.092
	3.5	17.85	3.0	73.105	2.273
	4.0	18.125	2.65	86.404	2.466
	4.5	18.125	2.35	84.023	2.465
16	2.5	18.1	3.6	40.442	1.065
	3.0	18.512	3.2	52.841	1.172

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
17	2.5	16.025	6.3	33.620	1.582
	3.0	15.925	6.8	37.971	1.722
	3.5	16.587	6.1	52.972	2.058
	4.0	17.6	4.3	74.031	2.281
18	2.5	16.525	4.2	38.424	1.717
	3.0	16.6	4.1	46.159	2.030
	3.5	17.462	3.8	70.767	2.397
	4.0	17.937	3.1	90.231	2.682
19	2.5	17.75	3.9	48.103	1.572
	3.0	17.8	2.9	57.926	1.853
	3.5	18.0	2.85	68.384	2.024
20	2.5	18.05	4.0	69.773	1.808
	3.0	18.337	3.7	100.855	2.327
	3.5	18.375	3.4	94.333	2.207
21	2.5	15.95	4.4	31.164	1.602
	3.0	15.95	4.6	39.930	2.032
	3.5	16.2	4.4	50.185	2.422
	4.0	16.45	4.4	60.841	2.743
	4.5	17.325	3.4	79.982	2.933
	4.75	17.225	3.0	73.950	2.888
22	2.5	17.025	5.7	47.673	1.639
	3.0	18.35	4.4	90.247	1.901
	3.5	18.387	3.3	96.874	2.274
23	2.5	17.4	3.3	43.679	1.572
	3.0	17.775	3.0	64.062	2.053
	3.5	17.975	2.8	73.327	2.203
	4.0	17.9	2.7	79.671	2.490
	4.5	17.8	2.5	69.611	2.301
24	2.5	17.988	3.4	52.782	1.493
	3.0	18.05	2.9	57.413	1.655

RAW SCORES - ASTRAND MAXIMAL OXYGEN UPTAKE TEST - MALES

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
25	3.5	16.625	5.9	37.369	1.454
	4.0	15.7	6.8	52.648	2.539
	4.5	16.325	6.5	71.477	2.939
	5.0	15.95	6.9	71.321	3.194
	5.5	16.975	5.75	99.433	3.468
	5.75	16.85	5.1	89.894	3.432
26	3.5	15.95	6.2	49.159	2.293
	4.0	15.937	7.0	55.842	2.496
	4.5	16.35	6.6	73.276	2.970
	5.0	16.862	5.9	90.830	3.261
	5.5	17.287	5.2	107.740	3.489
	5.75	17.4	4.175	102.667	3.457
27	3.5	17.525	4.5	53.364	1.667
	4.0	18.0	4.0	76.263	2.024
	4.5	18.625	3.4	99.405	2.011
	5.0	18.675	3.25	103.127	2.062
28	3.0	18.0	6.25	50.913	1.048
	4.0	17.15	5.0	74.624	2.551
	4.5	16.7	4.4	74.533	3.125
	5.0	17.65	4.8	142.202	4.103
29	3.5	17.175	5.05	68.953	2.358
	4.0	17.65	4.6	104.123	3.060
	4.5	17.5	4.7	105.875	3.284
	5.0	17.65	4.5	129.949	3.686
30	4.0	15.625	4.7	55.346	3.029
	4.5	16.05	4.6	78.692	3.905
	5.0	16.325	4.35	89.978	4.211
	5.5	16.675	4.25	114.213	4.870
	6.0	17.125	3.6	132.015	5.105

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
31	3.5	17.963	4.5	83.422	2.144
	4.0	18.175	4.3	104.962	2.471
	4.5	18.125	4.375	122.371	2.933
	5.0	17.9	3.75	98.52	2.805
32	3.5	16.425	4.2	59.883	2.751
	4.0	17.75	4.0	68.218	2.027
	4.5	18.2	3.4	87.935	2.252
	5.0	17.0	3.4	85.699	3.209
33	3.5	16.125	4.4	51.328	2.525
	4.0	16.588	4.1	70.627	3.118
	4.5	17.138	3.6	85.969	3.311
	5.0	17.5	3.25	102.739	3.581
34	3.5	16.25	4.6	51.760	2.437
	4.0	16.65	4.3	67.686	2.899
	4.5	17.5	3.3	91.658	3.183
	5.0	17.725	2.9	98.513	3.245
35	3.5	15.975	4.4	49.723	2.572
	4.0	16.413	4.4	60.150	2.741
	4.5	16.225	4.575	64.999	3.086
	5.0	16.8	4.2	86.069	3.546
	5.5	16.95	3.7	82.768	3.362
36	3.5	15.938	4.6	28.088	1.434
	4.0	15.9	4.8	49.894	2.544
	4.5	16.225	4.8	66.475	3.116
	5.0	17.538	3.45	111.455	3.773
	5.5	17.5	3.0	119.934	4.260

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
37	3.5	17.275	5.1	69.650	2.285
	4.5	17.287	5.1	87.298	2.850
	5.0	17.4	5.0	99.183	3.181
	5.0	17.5	4.6	101.841	3.186
	5.25	17.462	4.7	109.602	3.451
	5.5	17.362	4.7	103.475	3.390
38	3.5	15.875	4.4	49.557	2.595
	4.0	15.75	4.9	54.598	2.873
	4.5	15.95	4.8	64.551	3.251
	5.0	15.775	5.0	71.389	3.715
	5.5	16.7	4.6	94.725	3.921
	6.0	17.525	3.4	126.281	4.312
	6.5	17.475	3.0	117.938	4.226
39	3.5	16.537	6.1	48.979	1.934
	4.0	16.688	6.1	60.104	2.259
	4.5	16.8	5.8	82.793	3.060
	5.0	16.9	5.8	88.796	3.169
	5.5	17.25	5.0	96.889	3.235
40	3.5	16.05	4.4	49.947	2.505
	4.0	16.3	4.3	62.682	2.962
	4.5	16.725	4.1	77.083	3.269
	5.0	16.9	3.9	88.231	3.593
	5.5	16.95	3.6	93.111	3.807
41	3.5	15.275	5.2	36.512	2.112
	4.0	15.45	5.2	44.997	2.503
	4.5	15.25	5.25	44.635	2.590
	5.0	15.775	5.1	55.694	2.884
	5.5	16.925	3.8	88.990	3.619
	5.75	17.1	3.5	89.875	3.528
42	3.5	16.4	6.2	52.043	2.132
	4.0	16.775	5.8	65.246	2.432
	4.5	17.975	4.0	102.092	2.742
	5.0	18.187	3.9	125.576	3.069

SUBJECT	BICYCLE LOAD KG	% OXYGEN	% CARBON DIOXIDE	VOL. EXP. S.T.P.D.	OXYGEN UPTAKE LITERS/MINUTE
43	3.5	16.688	4.1	51.102	2.191
	4.0	16.35	4.3	57.647	2.688
	4.5	16.375	4.35	63.624	2.938
	5.0	16.7	3.9	79.886	3.455
	5.5	17.2	3.45	92.976	3.544
44	3.5	15.775	6.8	51.359	2.428
	4.0	15.9	6.7	58.255	2.677
	4.5	16.037	7.0	71.141	3.089
	5.0	17.087	5.4	90.496	3.205
45	3.5	16.5	6.4	52.433	2.053
	4.0	17.225	5.4	73.518	2.399
	4.5	17.425	4.9	80.074	2.517
46	3.5	16.55	4.15	56.510	2.514
	4.0	16.263	4.4	57.367	2.723
	4.5	16.7	4.2	65.813	2.794
	5.0	17.15	3.8	88.662	3.354
47	3.5	16.7	3.9	65.666	2.840
	4.0	16.8	3.8	85.821	3.626
	4.5	17.05	3.5	93.239	3.729
	5.0	17.375	3.2	111.379	4.068
48	3.5	16.15	4.25	58.714	2.894
	4.0	16.988	3.5	89.952	3.659
	4.5	17.3	3.1	97.432	3.681

RAW DATA - SJOSTRAND BICYCLE TEST ONE - FEMALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC_{170}
01	118	136	173	162	350	697	670.684
02	117	143	173	171	363	548	533.089
03	125	145	176	195	432	671	628.794
04	115	141	155	180	360	540	648.350
05	132	155	187	180	576	941	729.870
06	118	136	155	180	348	531	672.423
07	123	161	173	174	548	722	670.185
08	103	136	170	174	576	941	948.955
09	91	120	155	183	548	894	1072.915
10	115	167	195	177	595	622	619.987
11	95	158	141	177	576	971	907.987
12	99	138	180	174	529	874	819.340
13	106	167	187	165	473	759	578.975
14	115	132	167	171	364	710	744.203
15	94	132	170	348	639	992	981.667
16	132	167	187	192	401	586	449.232
17	102	134	176	186	595	1018	965.002
18	113	132	167	280	522	874	914.170
19	129	155	180	171	576	672	624.213
20	118	161	180	177	558	747	649.326
21	97	130	170	168	522	889	924.304
22	101	136	167	183	567	941	969.078
23	101	130	155	177	548	697	875.486
24	85	129	180	165	520	817	764.984

RAW DATA - SJOSTRAND BICYCLE TEST TWO - FEMALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC_{170}
01	101	145	167	171	529	685	715.084
02	118	136	167	165	356	520	555.592
03	115	123	173	207	388	759	740.885
04	110	120	141	174	354	522	847.141
05	122	145	155	177	363	548	676.336
06	118	164	173	183	531	627	591.966
07	106	145	176	174	558	735	712.870
08	102	155	176	180	567	941	811.742
09	129	145	170	216	452	909	900.182
10	115	145	184	168	548	710	644.166
11	92	123	155	183	595	1018	1217.177
12	129	161	173	372	513	748	664.839
13	106	136	164	192	539	735	814.127
14	117	145	180	177	394	747	645.377
15	102	136	170	336	675	920	935.667
16	123	143	176	159	324	501	471.800
17	108	138	173	189	548	910	884.840
18	118	122	170	256	486	844	851.650
19	129	150	167	171	363	548	571.670
20	111	158	180	174	548	735	650.430
21	100	130	155	174	522	874	1052.088
22	103	134	167	177	558	925	966.077
23	89	132	176	174	548	864	827.293
24	90	127	164	174	558	735	814.986

RAW DATA - SJOSTRAND BICYCLE TEST ONE - MALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC_{170}
25	117	136	167	558	910	1365	1424.263
26	108	134	161	567	925	1365	1489.636
27	145	167	180	567	759	941	818.547
28	122	150	173	529	941	1278	1234.220
29	114	138	161	520	956	1321	1483.641
30	97	123	155	539	910	1504	1736.324
31	127	150	164	529	672	879	903.530
32	123	130	173	520	848	1278	1255.627
33	111	145	176	548	925	1430	1319.430
34	129	153	176	477	874	1181	1103.823
35	113	145	176	331	786	1126	1067.567
36	96	129	176	421	753	1330	1249.758
37	105	129	161	520	1075	1608	1806 684
38	123	150	173	722	1075	1658	1547.559
39	108	134	158	558	925	1278	1448.189
40	102	145	170	510	1094	1455	1449.409
41	96	111	153	539	848	1356	1606.773
42	110	129	170	520	848	1191	1214.341
43	95	113	130	520	894	1213	2011.415
44	106	132	167	558	910	1504	1536.323
45	155	180		833	1168		1034.002
46	129	161		510	817		903.344
47	110	129	158	595	1033	1386	1611.965
48	114	138	158	662	894	1409	1546.210

RAW DATA - SJOSTRAND BICYCLE TEST TWO - MALES

SUBJECT	HR1	HR2	HR3	KPM1	KPM2	KPM3	PWC_{170}
25	129	150	170	558	941	1365	1354.632
26	107	130	161	548	925	1278	1417.213
27	148	173	187	567	659	971	738.717
28	148	173	187	567	941	1300	1351.032
29	111	136	173	558	941	1300	1485.184
30	107	136	173	576	1112	1685	1648.969
31	134	148	164	539	710	910	983.546
32	117	136	173	510	910	1321	1306.237
33	106	143	167	548	910	1343	1333.386
34	115	141	173	531	889	1244	1218.687
35	141	167	200	548	925	1321	940.036
36	101	150	187	513	1046	1427	1250.720
37	101	139	167	567	1213	1577	1652.876
38	118	141	173	722	1112	1658	1606.546
39	129	150	164	558	910	1278	1368.046
40	102	141	173	504	1046	1427	1400.679
41	118	136	170	735	1075	1630	1636.755
42	108	125	164	520	864	1170	1263.961
43	101	132	170	505	1131	1480	1521.320
44	108	132	167	548	941	1430	1483.808
45	125	164	180	539	879	1094	971.737
46	132	170	180	548	894	1094	945.643
47	107	132	161	548	879	1541	1575.395
48	115	141	158	624	925	1168	1307.646

RAW DATA - PROGRESSIVE STEP TEST ONE - FEMALES

SUBJECT	HR1	HR2	HR3	STEP1*	STEP2	STEP3	STEP170
01	129	158	176	4.23	7.28	8.68	8.23
02	136	158	176	4.23	5.63	7.28	6.72
03	145	161	187	4.20	5.60	7.31	6.12
04	122	158	176	4.20	7.31	8.71	8.25
05	155	170	180	4.20	5.60	7.31	5.91
06	132	158	184	4.20	7.31	8.71	7.78
07	148	176	184	4.20	5.60	7.31	5.75
08	125	161	167	4.20	7.31	8.71	8.64
09	129	145	173	4.20	7.31	10.11	9.94
10	138	161	176	4.20	7.31	10.11	9.00
11	129	158	180	4.23	7.28	11.51	9.69
12	123	167	176	4.20	7.31	8.71	7.92
13	127	161	176	4.23	7.28	8.68	8.12
14	143	161	176	4.20	5.60	7.31	6.64
15	115	145	173	4.20	7.31	10.11	9.82
16	150	167	184	4.23	7.28	8.68	7.12
17	120	136	170	4.23	7.28	10.08	10.32
18	129	158	173	4.20	7.31	10.11	9.38
19	123	132	161	2.82	4.23	7.08	8.12
20	145	167	176	4.23	5.63	7.29	6.39
21	123	150	167	4.20	7.31	8.71	9.16
22	113	129	173	4.23	7.28	11.51	11.34
23	141	167	195	4.23	7.08	9.88	7.31
24	101	132	173	4.20	7.31	10.11	10.02

* Step tests are measured in meters per minute with a stepping rate of twenty-eight steps per minute.

RAW DATA - PROGRESSIVE STEP TEST TWO - FEMALES

SUBJECT	HR1	HR2	HR3	STEP1	STEP2	STEP3	STEP170
01	120	145	161	4.23	7.28	8.68	9.80
02	141	167	176	4.20	5.60	7.31	6.40
03	138	161	180	4.20	5.60	7.31	6.46
04	136	161	176	4.20	7.31	8.71	8.14
05	155	173	184	4.20	5.60	7.31	5.63
06	141	161	180	4.20	7.31	8.71	7.82
07	142	167	187	4.20	5.60	7.31	6.01
08	118	141	153	4.20	7.31	8.71	10.97
09	129	155	180	4.20	7.31	10.11	8.98
10	132	161	184	4.20	7.31	10.11	8.45
11	115	141	164	4.23	7.28	8.68	9.47
12	132	164	180	4.20	7.31	8.71	7.81
13	122	161	176	4.20	7.31	8.71	8.14
14	153	173	191	4.20	5.60	7.31	5.51
15	118	153	173	4.20	7.31	10.11	9.52
16	150	167	180	4.23	5.63	7.28	6.15
17	115	143	161	4.20	7.31	10.11	11.06
18	129	150	167	4.20	7.31	10.11	10.52
19	129	148	164	2.83	4.23	7.38	7.77
20	148	170	184	4.23	5.63	7.23	5.94
21	120	153	170	4.20	7.31	8.71	8.76
22	115	145	170	4.23	7.28	10.08	10.03
23	118	158	187	4.23	7.08	9.88	8.34
24	105	136	180	4.20	7.31	10.11	9.51

RAW DATA - PROGRESSIVE STEP TEST ONE - MALES

SUBJECT	HR1	HR2	HR3	STEP1	STEP2	STEP3	STEP170
25	134	153	167	7.28	8.60	10.08	10.25
26	107	136	161	7.28	10.08	12.91	13.76
27	161	180	187	7.28	10.08	11.51	8.67
28	155	170		7.28	8.68		8.68
29	145	155	161	7.28	8.68	10.08	11.48
30	98	115	158	5.60	8.71	12.94	14.53
31	153	167		7.28	8.68		8.98
32	103	123	143	4.30	8.71	10.11	14.61
33	117	148	167	5.60	8.71	11.54	11.65
34	136	170	184	7.31	10.11	11.54	10.23
35	141	150	167	5.60	7.31	8.71	9.19
36	141	167	184	7.31	10.11	11.54	10.25
37	130	153	161	7.28	10.08	11.51	12.55
38	150	161	167	7.31	8.71	10.11	10.42
39	122	145	161	7.31	10.11	12.94	14.02
40	127	161	173	7.31	10.11	12.94	11.97
41	138	161	170	7.31	10.11	11.54	11.43
42	100	141	170	5.63	10.08	12.91	12.98
43	138	161	176	7.31	10.11	11.54	10.96
44	148	155	167	7.28	8.68	11.51	12.14
45	129	150	167	7.28	10.08	11.51	12.01
46	130	173		7.31	11.54		11.24
47	118	145	155	7.08	11.34	12.74	15.11
48	122	148	176	7.31	10.11	12.94	12.34

RAW DATA - PROGRESSIVE STEP TEST TWO - MALES

SUBJECT	HR1	HR2	HR3	STEP1	STEP2	STEP3	STEP170
25	148	170	176	7.28	8.68	10.08	9.16
26	129	138	153	7.28	10.08	12.91	16.98
27	158	176	187	7.28	8.68	11.51	8.65
28	118	165	173	5.60	8.71	10.11	9.52
29	136	153	161	7.28	8.68	10.08	10.83
30	117	141	164	7.31	10.11	11.54	12.30
31	132	161	171	4.23	7.28	8.68	8.45
32	120	148	173	7.31	10.11	12.94	12.56
33	113	145	173	5.60	8.71	11.54	11.22
34	132	158	180	5.60	8.71	10.11	9.40
35	125	161	173	2.80	7.31	8.71	8.37
36	130	161	187	7.31	10.11	11.54	10.45
37	132	145	158	7.28	8.68	10.08	11.37
38	134	148	164	7.31	8.71	10.11	10.70
39	127	143	155	7.31	10.11	12.94	15.77
40	125	153	173	7.31	10.11	12.94	12.40
41	127	155	170	7.31	10.11	11.54	11.56
42	141	170	184	7.28	10.08	11.51	10.11
43	118	141	158	7.08	9.88	11.34	12.76
44	134	145	155	7.28	8.68	10.08	12.06
45	136	161	176	7.28	10.08	11.51	10.93
46	127	173		7.31	8.71		8.62
47	127	155	170	7.08	11.34	12.74	12.98
48	114	145	167	7.31	10.11	12.94	13.06